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Australian Mosses — new chromosome numbers and a compilation of chromosome data

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Abstract

Meiotic chromosome numbers, of some 180 collections are presented, comprising 80 species in 57 genera of Australian mosses from the following 29 families: Bartramiaceae, Brachytheciaceae, Bruchiaceae, Crypheaceae, Daltoniaceae, Dicranaceae, Ditrichaceae, Echinodiaceae, Encalyptaceae, Fabroniaceae, Fissidentaceae, Funariaceae, Grimmiaceae, Hedwigiaceae, Hypnodendraceae, Hypopterygiaceae, Lembophyllaceae, Leucobryaceae, Meteoriaceae, Mitteniaceae, Mniaceae, Neckeraceae, Pottiaceae, Pterobryaceae, Ptychomniaceae, Racopilaceae, Rhizogoniaceae, Sematophyllaceae, Thuidiaceae. Many of these counts (40) are new records for Australian mosses while the others are additional reports or confirmation of previously published chromosome numbers.

The identity of a specimen named as *Philonotis harrisi* Geh. *nom nud.* for which a chromosome count was published previously, has been updated and corrected to *Philonotis tenuis* (Taylor) Reichardt. Additional data and name corrections for some of the New Zealand moss chromosome reports by Ramsay (2009) for Funariaceae and Pottiaceae are included.

Introduction

Australia has an interesting and varied moss flora of approximately 1100 species (Streimann & Klazenga 2002) occurring in a wide range of habitats and vegetation types from desert to *Eucalyptus* forests and subtropical rainforests, in climates from subalpine to temperate, subtropical and tropical with a variety of rainfall regimes. The *Flora of Australia* project (McCarthy 2006) is exploring the taxonomy, distribution and species diversity of mosses in Australia.

During the last forty five years there have been many publications reporting chromosome numbers and chromosome behaviour in mosses from Australia and related areas such as Papua New Guinea and New Zealand. Some studies have been carried out separately for New Zealand mosses but most Australian results have been published by the author (Ramsay 1964, 1966b, 1967a, 1967b, 1973, 1974, 1977, 1979, 1982, 1983a, 1983b, 1983c, 1985, 1987, 1988, 1992, 1993, 1997, 2006, 2008, 2009), or in collaboration with others,

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e.g. Ramsay & Lewinsky (1984), Ramsay & Vitt (1986), Ramsay & Bergstrom (1995), Ramsay et al. (1995), Ramsay & Spence (1996), Ramsay et al. (2002).

In total, chromosome numbers for about 10% of Australian species have been published together with information on behaviour and karyotypes of chromosomes at meiosis and mitosis (Ramsay 1982, 1983c) and sex determination (Ramsay & Berrie 1982). The various cytological studies have shown that in the Australasian region the numbers and morphology of the chromosomes examined are comparable with those obtained in other parts of the world (Ramsay 1969, 1974, 1983b; Fritsch 1991). Some unique data for Australia and New Zealand include the low chromosome numbers n=4, 5 for Hypnodendraceae (Ramsay 1974, 1987, 1988) while the possible presence of sex chromosomes in *Macromitrium*, as indicated by dimorphic bivalents, anisospory and dwarfism of males, has been discussed (Ramsay 1966a, 1979, 1983c; Ramsay & Berrie 1982; Smith & Ramsay 1982; Ramsay & Vitt 1986). In addition, the presence of 'm' chromosomes in *Macromitrium* (Ramsay 1966a, 1974, 1983c) and various other mosses, e.g. *Dicranoloma* by Ramsay (1987, 1988) in Australia, and for other mosses in Europe, North America and Japan (summarised in Anderson & Bryan 1987) and demonstrated in *Plagiomnium affine* by Klos et al. (2001), have been noted. Intraspecific polyploidy is reported in a number of mosses (e.g. *Hypopterygium tamarisci* as *H. rotulatum* in Ramsay 1967b) while chromosome numbers, resulting from polyploidy in various colonising species, are particularly high in the Bryaceae, Pottiaceae and Funariaceae (Ramsay 1974, 1983c) increasing genetic diversity and possibly accounting for their success in stressful environments.

Variations in numbers and size as well as behaviour of bivalents between taxa at meiosis are demonstrated in photomicrographs in publications by many authors and summarised in Ramsay (1983c: figs 66–140). Relatively large chromosomes and small numbers are found in families such as Polytrichaceae, Hypnodendraceae, Rhizogoniaceae, while predominately high chromosome numbers and smaller-sized chromosomes occur in others, e.g. Pottiaceae and Funariaceae. Very small m-chromosomes that have specialised behaviour occur in a variety of mosses, e.g. *Macromitrium, Entliostliodon, Dicranoloma.* Many Japanese bryologists such as S. Inoue, Yano, Ono, Iwatsuki (see Fritsch 1991) have examined mitotic chromosomes and prepared karyotype formulae to demonstrate similarities or differences between related and unrelated moss taxa (for detailed comments refer to Ramsay 1982, 1983c).

Methods

Techniques follow those of Ramsay (1974, 1982, 1983c), i.e. fixing and staining in aceto-orcein or aceto-carmine, with preservation of slides by freezing with carbon dioxide and mounting in euparal. These permanent slides are still in good condition and numbers able to be checked more than 40 years later. All chromosome vouchers are listed under the HPR number (e.g. *10/84*)

Only drawings are presented here but earlier publications, referred to in the text (e.g. Ramsay 1966a, 1966b, 1974, 1983a, 1983c, 1987; Ramsay & Vitt 1986), demonstrate the appearance of the meiotic patterns for many species photographically.

The species names used here have been checked against Streimann & Klazenga (2002) and Tropicos (2011), sometimes resulting in changes of names used for earlier counts.

Where possible the earlier names have been brought up to date and referred to here. The familial classification used here follows that of Buck & Goffinet (2000), Goffinet & Buck (2004), Goffinet et al. (2008, 2010), and where genera have been transferred to different families in this new classification it has been noted in the text.

Chromosome Numbers

The present studies provide chromosome counts for previously unpublished taxa, additional numbers where these differ from earlier reports, and some extra data included in support of previously published studies. The results are arranged alphabetically by family, genus and species. Table 1 summarises the species examined, chromosome number, collector's name and voucher number with locality data for taxa studied and missing data (+) on localities for results published in Ramsay 1983c. Voucher specimens have been deposited in the National Herbarium of New South Wales (NSW). The chromosome numbers for 80 species in 57 genera and 29 families of Australian mosses are reported here.

Family Bartramiaceae

In Australia, the family consists of the following genera, *Bartramia, Breutelia, Conostomum*, and *Philonotis* (Gilmore 2006: 248–270). Chromosome numbers obtained previously are recorded in Fritsch (1991) and Goldblatt & Johnson (1994–2006). These include n=8, 9, 12, 16, 36, for *Bartramia* from India, Europe, North America, Japan and Australia; while *Conostomum* has n=8, 16 from Australia, U.S.A., Shetland Is., and South Georgia. *Philonotis* counts are mainly n=6 with a few n=12 from India, U.S.A., Japan, Europe, Australia (Ramsay 1967, 1974) and New Zealand (Ramsay 2009) while *Breutelia* has n=6 for species from Japan, Europe, Chile, South Georgia (Fritsch 1991) and Australia (Ramsay 1967, 1974, 1983c).

Additional data for Australia reported here include new records for *Breutelia* and *Philonotis* species and numbers are confirmed for the following two species of *Breutelia*.

1. ***Breutelia affinis*** (Hook.) Mitt n=6 Fig. 1.1

2. ***Breutelia pendula*** (Sm.) Mitt. n=6 Fig. 1.2

The recorded chromosome number n=6 (Ramsay 1967, 1974) is supported here for both *B. affinis* (*35/79*) and for *B. pendula* (*50/81*), the latter being the first count from Tasmania for *B. pendula*. A photomicrograph of the bivalents for the previous count for *B. pendula* appears in Ramsay (1983c: fig. 33).

3. ***Breutelia pseudophilonotis*** (Müll.Hal.) Watts & Whitel. n=6 Fig.1.3

There are no previous chromosome records for *B. pseudophilonotis*, a recently accepted species (Gilmore 2006: 260) (Table 1).

4. ***Philonotis tenuis*** (Taylor) Reichardt n=6 Figs 1.4 & 1.5

The chromosome number n=6 (*58/63*) has previously been recorded for a species identified as *Philonotis harrisi* Geh.in Watts & Whitel. (Ramsay 1967a, 1974), a *nom. nud.* based on a specimen from Cambewarra, N.S.W. (*W.W. Watts 2643*; NSW, SYD; Watts & Whitelegge1906). In his revision of the genus for Australia, Gilmore (2006) does not mention having examined the specimen of *P. harrrisi* but when the above

Table 1. Chromosome numbers for Australian mosses.

All collections listed have the HPR voucher number regardless of the collector's number. * indicates a new species record and HPR number, + gives the voucher number and/or locality details lacking for records published in Ramsay 1983c; numbers in **bold** indicate additional number reports for species previously published; those without a prefix indicate additional reports that correspond to previously published Australian records.
Collections are by Ramsay unless cited otherwise.

Species	Chromosome number	Voucher number and locality details
Acrocladium chlamydophyllum	n=11(10+m)	TAS.: *53/81* Lake Dobson; *58/81* Liffy Falls
	n=20	TAS.: *49/81* Hartz Mt
+*Achrophyllum dentatum*	n=12	VIC.: *7/79* Sherbrooke Forest (Ramsay 1983c)
	n=c.20	*11/79* Sherbrooke Forest
	(irregular meiosis)	
**Aloina aloides* var. *ambigua*	n=26	N.S.W.: *27/83* Marulan (*W.B. Schofield 79240*)
Barbula calycina	n=13	N.S.W.:*3/74*, *7/74* Moss Vale; *29/79* Mt Wilson; *31/83* Wilson R; *43/83* Blackheath; *52/83* Gordon Falls, with *W.B. Schofield*
Braithwaitea sulcata	n=10	N.S.W.: *47/82* Mt Wilson
Breutelia affinis	n=6	N.S.W.: *35/79* Mt Wilson.
Breutelia pendula	n=6	TAS.: *50/81* Lake Dobson
*Breutelia pseudophilonotis	n=6	N.S.W.: *55/83* Echo Point
**Bryoerythrophyllum dubium*	n=13	N.S.W.: *57/83* Goulburn
**Calymperes tenerum*	n=10	QLD: *12/84* Cardwell (*H. Streimann 523*, CBG 28812); *10/84* Ingham (*H. Streimann 548*, CBG 28836)
**Camptochaete arbuscula* var. *arbuscula*	n=11	N.S.W.: *29/83* Sugarloaf Mt (*W.B. Schofield 79130*), *35/83* Woolgoolga
**Ceratodon purpureus* subsp. *convolutus*	**n=6**	A.C.T.: *43/84* Tidbinbilla; N.S.W.: *56/83* Goulburn; VIC.: *15/77* Mt William
	n=13	N.S.W.:*48/82* Kiandra; *46/84* Culcairn; *47/82* Yarrangobilly
**Cryphaea tenella*	n=11(10+m)	N.S.W.: *3/83* Minnimurra Falls; *25/79* Wauchope; *37/84* Mt Warning National Park
Cyathophorum bulbosum	n=5	VIC.: *21/79* Sherbrooke Forest
+*Dendrocryphaea tasmanica*	n=11	TAS.: *11/81* Natural Arch
(as *Cryphaea tasmanica* Ramsay 1983c)		

Dicranella dietrichiae	n=12	N.S.W.:*1/71* Epping, Sydney; *7/71* Cheltenham, Sydney; *23/73* Leura; *5/74* Moss Vale; *24/79*, *31/83*, *37/83*, *38/83*, *42/83* Wilson River–Wauchope area.
Dicranoloma dicarpum	n=7	TAS.: *56/81* Lake Dobson
Ditrichum difficile	n=13	A.C.T.: *10/87* Brindabellas; *42/84* Tidbinbilla; N.S.W.: *59/82* Yarrangobilly; *21/84* Alstonville; *30/84* Mt Warning
**Eccremidium pulchellum*	n=13	VIC.: *7/77* Hamilton
+*Echinodium hispidum*	n=10	VIC.: *18/79* Sherbrooke; N.S.W.: *7/75* Coffs Harbour (Ramsay 1983c); *18/81*, *22/81* Wiangarie State Forest
**Encalypta vulgaris* var. *vulgaris*	n=13	N.S.W.: *17/80* Yarrangobilly; *47/83* Jenolan Caves, *48/83* ibid. (*W.B. Schofield 79212*)
**Entosthodon apophysatus*	n=24	Vic.: *6/77* Hamilton; QLD: *44/81* Bunya State Forest
**Entosthodon radians*	n=52	N.S.W.: *3/87* Dorrigo, *W.B. Schofield 90756*; *53/83* Wilson River, Wauchope; *8/76* Kuringai Chase near Sphinx, Sydney; QLD: *16/84* Coolum Mt
**Entosthodon subnudus* var. *gracilis* (=*Funaria gracils* & *F. cuspidata*) (*F. cuspidata* Ramsay 1974)	n=26	N.S.W.: *41/83* Woolgoolga; *6/74* Ruscutters Bay Park, Sydney (*R.G. Coveny 5546*); *27/81* Bulladelah
**Euptychium cuspidatum*	n=5	N.S.W.: *6/75* Coffs Harbour *B.O. van Zanten*
Fabronia australis	n=30	N.S.W.:*1/74* Moss Vale
	n=20	QLD: *10/84* Atherton (*H. Streimann 548* CBG 29552)
	n=11	N.S.W.*19/80* Yarrangobilly
Fissidens oblongifolius	n=16	VIC.: *16/79* Sherbrooke Forest
Fissidens pallidus	n=10	VIC.: *5/79* Sherbrooke Forest
Funaria hygrometrica	n=28	N.S.W.: *4/74* Moss Vale; VIC.: *1/77* Hamilton
**Garovaglia elegans* subsp. *dietrichiae*	n=10	QLD: *11/84* Atherton (*H. Streimann 414* CBG 29252)
Glyphothecium sciuroides	n=7	N.S.W.: *50/84* Megalong Valley
**Grimmia pulvinata* var. *africana*	n=26	N.S.W.: *21/73* Blackheath
**Grimmia trichophylla*	n=13	N.S.W.: *17/84* Hallidays Point,
**Gymnostomum calcareum*	n=13	S.A.: *53/84* Coorong
**Hampeella pallens*	n=6	QLD: *33/81* Brindle Creek; N.S.W. *49/83* Wiangarie; *50/83* Wauchope
	n=12	N.S.W.: *9/83* Wiangarie State Forest
**Hedwigia ciliata*	n=11 (10+m)	N.S.W.: *63/82* Bowral; *39/83* Wauchope

**Hedwigidium integrifolium*	n=11	A.C.T.: *55/84* Tidbinbilla
**Hypnodendron comatulum*	n=4	QLD: *1/88*, *2/88* Mt Bartle Frere (*I.G. Stone s.n.*)
Hypnodendron vitiense subsp. *australe*	n=9	N.S.W.: *2/87* Dorrigo (*W.B. Schofield 90754*)
Hypopterygium tamarisci	n=9	N.S.W.: *1/75* Cambewarra; *7/80* Megalong Valley
	n=18	N.S.W.: *3/75* Cambewarra
Lembophyllum clandestinum	n=10	VIC.: *19/77*, *30/77* Mates Rest; *17/79* Sherbrooke; N.S.W.: *3/86* Wilson River
**Leptostomum erectum*	n=6 & n=12	N.S.W.: *2/76* Mt Wilson
**Leucobryum aduncum* var. *scalare*	n=6	VIC.: *19/79* Sassafras Creek; N.S.W:*14/81* Bulladelah; *13/75* Kempsey
Leucobryum candidum (?=*L. aduncum* var. *aduncum*)	n=11	N.S.W.; *5/72* Royal National Park; *1/73* Springwood
Lopidium concinnum	n=12 & **n=c. 18 (–21)**	VIC.: *14/79* Sassafras
Mesochaete undulata	n=10	N.S.W.: *36/83* Woolgoolga
+*Mittenia plumula*	n=10	VIC.: *22/79* Sherbrooke; N.S.W.: Mt Wilson
Orthotrichum tasmanicum var. *tasmanicum*	n=6	A.C.T.: *9/87* Brindabella Ra; N.S.W.: *6/88* Jenolan Caves (*A.J. Downing*)
Papillaria crocea	n=11	N.S.W.: *40/83* Wauchope (*W.8. Schofield*)
**Philonotis tenuis* (as *P.harrisi* in Ramsay1974)	n=6	N.S.W.: *30/81* Barrington Tops with *D.H.Vitt*; QLD: *58/63* Eungella
+*Physcomitrium pyriforme* (as *P. conicum* in Ramsay 1983c)	n=26	N.S.W.:*16/80* Yarrangobilly; *24/81* Wiangarie
Plagiomnium novae-seelandiae	n=14 (gametophytic mitosis)	N.S.W.: *4/88* Jenolan Caves with *P.M. Selkirk*
Ptychomnion aciculare	n=7	TAS.: *59/81* Hartz Mts
Pyrrhobryum medium (as P.brevifolium in Ramsay 1967, 1974)	n=6	QLD: 1/64 Mt Spec
Pyrrhobryum mnioides (as Rhizogonium mnioides in Ramsay1967, 1974)	n=12	VIC.: 16/77 & 18/77 Mates Rest, Otway
Pyrrhobryum paramattense (as *Rhzogonium paramattense* in Ramsay 1967, 1974)	n=6	N.S.W.: *11/75* Kempsey; *8/82* Wattagan State.Forest; *16/81*, *17/81* Wiangaree SF; *2/72* Royal National Park; VIC.: Mates Rest
	2n=12 (premeiotic mitosis)	VIC.: *12/79* Sherbrooke
Racopilum cuspidigerum var. *convolutaceum*	n=10	N.S.W.: *46/83* Big Scrub; *33/79* Mt Wilson; *12/75* Garie Beach (*P. Wallin*); *9/75* Comboyne; A.C.T.: *11/76* Tidbinbilla

**Radulina borbonica*	n=6	QLD: *9/84* Cardwell. (*H. Streimann*)
Rhizogonium novaehollandiae (Ramsay 1983c: fig. 104)	n=5	TAS.: *71/64* Mt Wellington
**Rhynchostegium muricatulum*	n=22	N.S.W.: *27/79* Wilson River; *39/83* Wauchope
	n=11	QLD: *25/84* Maleny, with *W.B. Schofield*
Rhynchostegium tenuifolium	n=11	N.S.W.: *40/84* Mt Warning; *31/79* Mt Wilson
	n=22	N.S.W.: *14/84* Megalong Valley
**Schistidium apocarpum*	n=13	N.S.W.: *49/82* Yarrangobilly Caves
Sclerodontium pallidum	n=11	N.S.W.: *7/76* Katoomba Falls
**Tetrapterum cylindricum*	n=26	VIC.: *14/77* Hamilton, N.S.W.: *23/81* Wiangaree State Forest
Thamnobryum pumilum	n=11(10+m)	N.S.W.: *45/83* Big Scrub
Thuidiopsis sparsa	n=11	N.S.W.: *2/75* Katoomba; *2/91* Macquarie University, Sydney; *32/84* Mt Wilson
**Tortella knightii*	n=13	N.S.W.: *20/84* Megalong Valley
	n=20	N.S.W.: *18/87* Jenolan Caves; *52/83* Gordon, Blue Mts
**Tortula andersonii*	n=14	N.S.W.: *46/82* Yarrangobilly Caves
	n=22	*46a/82* loc. cit.
**Tortula antarctica*	n=26	S.A.: *35/84* Port McDonnell
**Tortula atrovirens*	n=21	N.S.W.: *48/84* Culcairn
Tortula muralis	n=48	VIC.: *21/77* Melbourne University; *13/77* Hamilton; N.S.W.: *30/79* Blackheath; *3/91* Macquarie Univ; *28/73* Echo Point
	n=24	N.S.W.: *25/73* Echo Point
Tortula papillosa	n=7	N.S.W.: *42/82*, *58/82* Yarrangobilly; *25/81* Mt Banks
**Tortula truncata*	n=26	VIC.: *12/77* Hamilton
**Trematodon* sp. *cf. T. baileyii*	n=14	QLD: *7/74* Crystal Cascades Cairns
**Trematodon flexipes*	n=14	N.S.W.: *2/69* Barrington House
**Trematodon longescens*	n=15 (14+m)	N.S.W.: *28/81* Bulladelah
**Trematodon longicollis*	n=15	N.S.W.: *12/81* Barrington Tops
**Trematodon suberectus*	n=14	QLD: *27/84* Mt Coot-tha Botanic Gardens, Brisbane
**Weissia brachycarpa*	n=12	N.S.W.: *42/83* near Glen Innes
Weissia controversa	n=13	N.S.W.: 9/76 Bobbin Head; *13/84* Megalong Valley; *5/74* (*R.G. Coveny 5556*)

collection was compared to specimens of *Philonotis tenuis* named by Gilmore, it was found to be identical and *P. harrisi* is thus placed into synonymy with *P tenuis*.

Newton (1973) recorded n=6 from gametophytic mitotic studies of *P. tenuis* from New Zealand. The chromosome voucher (*58/63*) named as *P. harrisi* from Eungella in Queensland in Ramsay (1967a, 1974) has been re-examined and corrected to *P. tenuis*. An additional report here (*30/81*) from Barrington Tops, New South Wales based on meiotic examination also records the number for *B. tenuis* as n=6.

Family Brachytheciaceae

The Brachytheciaceae is represented in Australia by only a small number of the 43 genera. The main genera present are *Brachythecium*, *Eurhynchium*, *Rhynchostegiella* and *Rhynchostegium*.

In Australia chromosome data are only available for the genus *Rhynchostegium* with worldwide reports providing a range of numbers: n=10, 11, 10+m, 12, 13+m, 20, 20+2m, 22 (Fritsch1991; Goldblatt & Johnson 1994, 2003, 2006). The higher numbers indicate intraspecific polyploidy and aneuploidy, and m-bivalents have been reported. Former counts for Australian species are n=22(20+2m) for *R. tenuifolium* (this includes the report of n=22 for R. *laxatum* in Ramsay 1974 which has been checked and the name corrected to *R. tenuifolium*). A report from New Zealand for *R. tenuifolium* is n=11 (Ramsay 2009).

5. *Rhynchostegium muricatulum* (Hook.f. & Wilson) Reichardt n=11 no illustration

n=22 Figs 1.8 & 1.9

These are the first chromosome records for *R. muricatulum*, formerly *Eurhynchium*. Two separate chromosome numbers are reported here — one collection (*25/84*) from Maleny in Queensland had a count of n=11, whereas two others (*27/79*, *39/83*, both from Wilson River, Wauchope, New South Wales but obtained at different times) had n=22 and were polyploid in origin. Meiotic behaviour was normal in each suggesting established allopolyploidy.

6. *Rhynchostegium tenuifolium* (Hedw.) Reichardt n=11 Fig.1.7

n=22 Fig. 1.6

Ramsay (1967a, 1974) obtained a chromosome count of n=22 with one or two m-bivalents for *R. tenuifolium* as *R. laxatum* (*14/66*) from Mt Wilson and one from the Royal National Park (*7/72*). An additional count of n=22 is recorded here from a later collection (*14/84*) from Megalong Valley (Table 1). Two other collections had a count of n=11, one (*31/79*) from the Royal National Park and the other (*40/84*) from Mt Warning.

Family Bruchiaceae

In Australia the family Bruchiaceae includes the two genera *Bruchia* and *Trematodon*, both terrestrial colonising species. *Bruchia* has the chromosome numbers n=14, 15, 16, 28, 30 recorded for species in U.S.A.(Fritsch 1991). Chromosome numbers have been reported for six species of *Trematodon* from Canada, USA and India, n=11, 12, 13+m, 13+2m, 14, 14+m, 28, and 28+2m indicating polyploidy and aneuploidy within the genus (Fritsch 1991, Goldblatt & Johnson 1994) as well as m-chromosomes in some species.

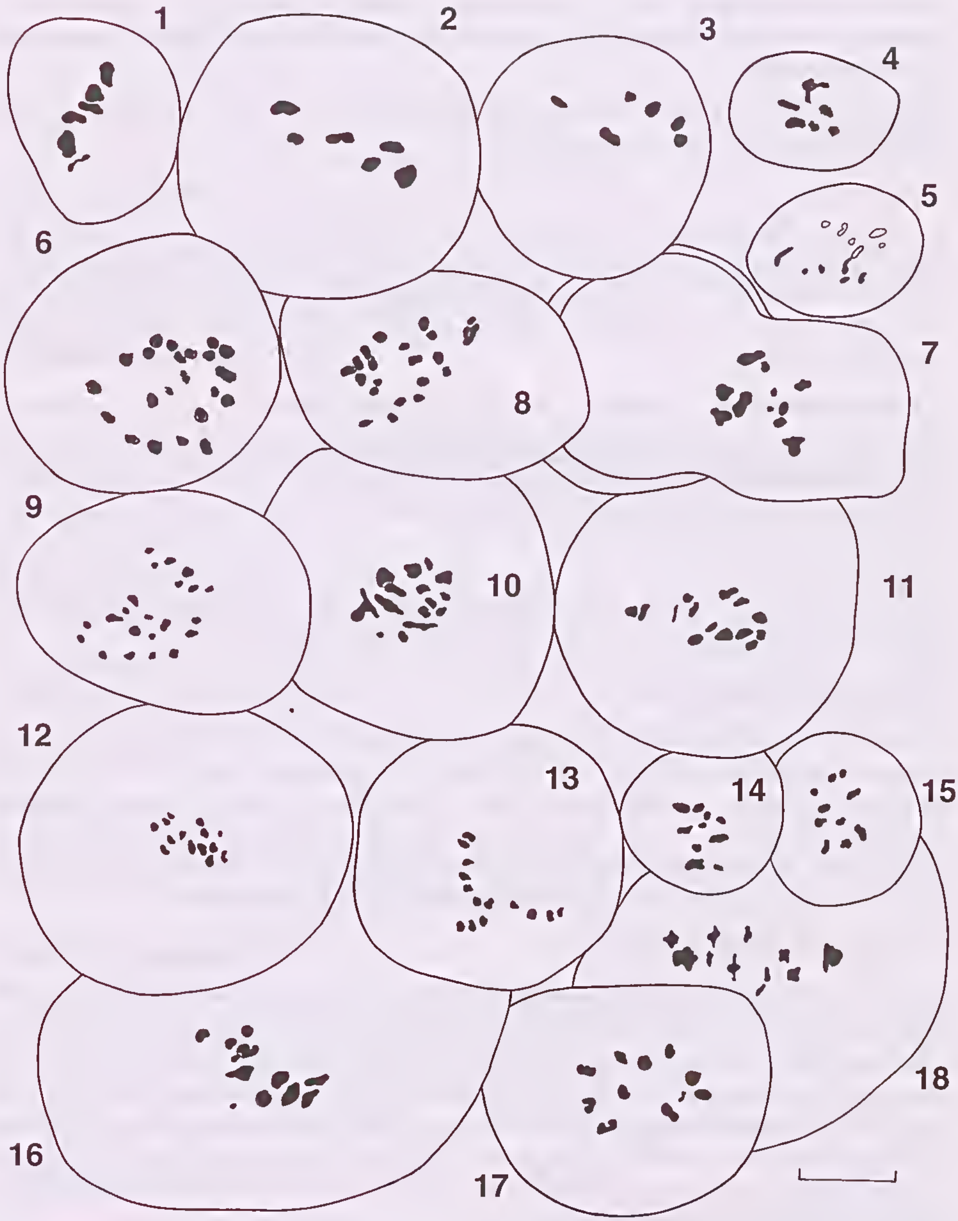

Fig. 1: 1–18. Chromosome numbers in Australian mosses (figures at Metaphase 1 of meiosis unless stated otherwise) — in families Bartramiaceae, Brachytheciaceae, Bruchiaceae, Calymperaceae, Cryphaeaceae. **1.** *Breutelia affinis* (*35/79*) n=6, a small bivalent is separating early; 2. *Breutelia pendula* (*50/81*) n=6; **3.** *Breutelia pseudophilonotis* (*55/83*) n=6; **4 & 5.** *Philontis tenuis:* **4.** (*30/81*) n=6; **5.** (*58/63*) n=6 Anaphase 1 showing 6 half bivalents at each pole; **6 & 7.** *Rhynchostegium tenuifolium:* **6.** (*7/72*) n=20; **7.** (*31/79*) n=11; **8 & 9.** *Rhynchostegium muricatulum:* **8.** (*27/79*) n=22; **9.** (*39/83*) n=22; **10.** *Trematodon suberectus* (*27/84*) n=14; **11.** *Trematodon* cf. *baileyi* (*7/74*) n=14; 12. *Trematodon longescens* (*28/81*) n=15 (14+m.); 13. *Trematodon flexipes* (*2/69*) n=14; **14 & 15.** *Calymperes tenerum:* **14.** (*12/84*) n=10; **15.** (*10/84*) n=10; **16 & 17.** *Cryphaea tenella:* **16.** (*3/83*) n=11 (10+m); **17.** (*25/79*) n=11(10+m); **18.** *Dendrocryphaea tasmanica* (*11/81*) n=11 (cf. fig 126 in Ramsay 1983c). Scale bar is 10 µm.

Trematodon, previously in the Dicranaceae, has been placed in the Bruchiaceae by Goffinet & Buck (2004) and has eight species recorded for Australia in Streimann & Klazenga (2002).

A count of n=14 has previously been reported for *T. suberectus* in New Zealand (Ramsay 2009), a species also present in Australia.

The following are the first Australian reports of chromosome numbers for *Trematodon* in Australia. Identification of specimens was difficult and the genus is under review at present by Seppelt & Ramsay. Five different species were examined cytologically- *T. longicollis, T. baileyi, T. longescens* (these latter two being related to *T. longicollis*), and two other species *T. flexipes* and *T. suberectus.* The collections were from Queensland and New South Wales.

7. Trematodon sp. (cf. *T. baileyi*) n=14 Fig. 1.11

One collection examined from Cairns, Queensland (*7/74*) is smaller than the *T. longescens* specimens, with a shorter seta and a capsule with a long neck and peristome teeth separate except at the base.This specimen had the chromosome number n=14 and lacked an m-chromosome. Being based on a small collection only, the lack of sufficient material makes it difficult to identify but its locality suggests it may be *T. baileyi,* which is a small endemic species from the Mulgrave River, Bellenden Ker region close to Cairns.

8. Trematodon flexipes Mitt. n=14 Fig. 1.13

T. flexipes is a small species with a short seta and a capsule with a neck about the same length as the urn. It is more widely distributed in Australasia than the other species, occurring in the more temperate regions of New South Wales, Victoria, Tasmania, Australian Capital Territory as well as in New Zealand and Macquarie Island. There are no previous chromosome counts. A collection of *T. flexipes* (*2/69*) from near Barrington Tops, New South Wales (Table 1) had the chromosome number n=14.

9. Trematodon longescens Müll.Hal. n=15 (14+m) Fig. 1.12

The distribution of *T. longescens,* an endemic Australian species, extends from far north Queensland along the coast and tablelands to Nowra south of Sydney with the most collections being from the Brisbane area of southeastern Queensland. There are no published illustations of *T. longescens.* The sporophyte has strong similarities to *T. longicollis* as illustrated in Magill (1981), Eddy (1988), Norris & Koponen (1990) and Magill & Rooy (1998) with the capsule neck consistently more than twice the length of the urn. The two species appear to differ in plant size, leaf set and structure, perichaetial leaves, the peristome and spore size.

The chromosome number n=15 (14+m) with an m-chromosome was determined for *T. longescens* (*28/81*) from Bulladelah, New South Wales.

10. Trematodon longicollis Michx. n=15 no illustration

T. longicollis is a very widespread species based on a type collection from North America and was first described in 1803 by Michaux. It seems to differ from *T. longescens* in leaf and sporophyte characteristics as explained above. Eddy (1988) has described and illustrated *T. longicollis* and records its distribution as pantropical and subtropical in Asia and Malesia. However, others give it as having a range into more temperate regions of Southern Africa (Magill 1991), eastern North America (Anderson & Crum

1981), India (Gangulee 1969), Papua New Guinea (Norris & Koponen 1990) and Japan (Noguchi 1987). For Australia, Streimann & Klazenga (2002) list *T. longicollis* as occurring only in Western Australia and Victoria, However, the revision in progress suggests it is more widespread with at least one collection (*S. Churchill*: CANB, NSW) extending its distribution to the northeastern tropics. There are still 50 collections made by I.G.Stone in northeastern Queensland, some of which may be *T. longicollis*, yet to be identified.

The chromosome number obtained for *T. longicollis* (*12/81*) from Barrington Tops, New South Wales is n=15, the same number as found in the collection of *T. longescens* examined in these studies, but lacking the m-chromosome.

11. Trematodon suberectus Mitt. n=14 Fig. 1.10

Trematodon suberectus is smaller than *T. longescens* with a shorter seta and a capsule with the neck less than twice as long as the urn. The collection studied here from Brisbane, Queensland (*27/84*; Fig. 1.9) had the number n=14. The chromosome number agrees with counts for two collections in New Zealand (Ramsay 2009).

Family Calymperaceae

The family Calymperaceae is represented mainly in tropical regions of Australia, although a few species are found in New South Wales. Five genera are listed for Australia (Reese & Stone 1995). The recorded chromosome numbers are n=13, 26 for one species of *Octoblepharum* from India, n=13 for three species of *Syrrhopodon* from India, Japan and U.S.A., and n=11 for one species of *Syrrhopodon* from Japan (Fritsch 1991). There are no previous chromosome reports for any Calymperaceae in Australia.

12. Calymperes tenerum Müll.Hal. n=10 Figs 1.14 & 1.15

Two collections of *C. tenerum* by Heinar Streimann from separate localities (*10/84*, *12/84* in North Queensland) had the chromosome number n=10.

Family Cryphaeaceae

The family Cryphaeaceae is a small tropical/subtropical family containing nine genera (Goffinet & Buck 2004). Following the revision by Enroth (1995, 1996) the genus *Cryphaea* is represented in Australia by three species (Streimann & Klazenga 2002). Chromosome numbers of n=10+m, 10+2m have been recorded previously for several species of *Cryphaea* from U.S.A., Europe and Australia (Fritsch 1991).

13. Cryphaea tenella (Schwägr.) Hornsch. ex Müll.Hal.
n=11 (10+m) Figs 1.16 & 1.17

The collections of *C. tenella* examined (*25/79*, *3/83*, *37/84*) came from three widely separate localities in New South Wales and all had the chromosome number n=11(10+m).

14. Dendrocryphaea tasmanica (Mitt.) Broth.
n=11 (10+m) Figs 1.18, 2.1 & 2.2

This was reported as *Cryphaea tasmanica* by Ramsay (1983c: fig. 126) with a count of n=11(10+m) but without locality or voucher number. These are added here (Table 1). The complement of n=11(10+m) as illustrated in Ramsay (1983c) is included here with the voucher number added.

Family Daltoniaceae

There are six genera present in Australia (previously in the family Hookeriaceae) and at present only two genera are recognised for the family Hookeriaceae (Goffinet & Buck 2008). A count is available for *Achrophyllum*.

15. Achrophyllum dentatum (Hook. & Wilson) Vitt. & Crosby

n=12	Fig. 2.17
n=c. 20	no illustration

The chromosome number n=20 was reported by Ramsay (1967a, 1974) for two collections (*9/64, 9/66*), one from N.S.W. the other from Victoria, of the only Australian species (as *Pterygophyllum dentatum*), with 80% of cells having abnormalities such as micronuclei and laggards.

In Ramsay (1983c: fig. 115) the chromosome number for *Achrophyllum dentatum* was reported as n=12 for a collection from Victoria, Sherbrooke Forest (*7/79*). The chromosome number of n=c. 20 is reported here for a separate collection (*11/79*) also from Sherbrooke Forest, Victoria. This is polyploid compared with the previous count, but no exact count was possible. Many meiotic irregularities were observed similar to those recorded and illustrated previously (Ramsay 1974) including multivalents and univalents as well as bivalents, while a bridge involving several bivalents at anaphase I suggested inversion hybridity. There was little evidence of any normal anaphase, and distribution of bivalents to poles was erratic. Tetrads were also abnormal with irregular spore numbers and laggards. This misbehaviour at meiosis suggests that the collection was possibly autopolyploid.

Family Dicranaceae

In Australia this family is represented by genera such as *Dicranella*, *Dicranoloma*, *Eucamptodon*, *Holomitrium*, *Leucoloma*, and *Sclerodontium*.

The genus *Dicranoloma* in Australasia consists of 26 species (Klazenga 2003). Ramsay (1967a, 1974, 1985, 2006) has published chromosome studies for the genus *Dicranoloma* in Australia, New Zealand and Papua New Guinea. Chromosome numbers reported so far include n=7, 8, 9 (7+2m), 12 from Australasia and n=14 for a single species from India (Fritsch 1991).

16. Dicranoloma dicarpum (Nees) Paris — n=7 — Fig. 2.5

A report of n=7, the first for Tasmania, is recorded here for a collection (*56/81*) of *Dicranoloma dicarpum* from Lake Dobson (Table 1) and agrees with previous numbers for this species (Ramsay 1974, 2006, 2009).

There are 12 species of *Dicranella* listed for Australia (Streimann & Klazenga 2002). The chromosome numbers for *Dicranella* include n=7, 12, 12+m, 13, 14, 15, 16 for nine species in India, U.S.A., Japan, Europe, Canada (Fritsch 1991, Goldblatt & Johnson 2003) including some with m-chromosomes. The only report for an Australian species is n=12 for *D. dietrichiae* (Ramsay 1967a, 1974) for which additional populations were examined here.

17. Dicranella dietrichiae (Müll.Hal) A.Jaeger — n=12 — Figs 2.3 & 2.4

The chromosome number n=12 is confirmed for seven additional populations of *D. dietrichiae* from different localities (*7/71, 23/73, 5/74, 24/79, 31/83, 37/83, 38/83,*

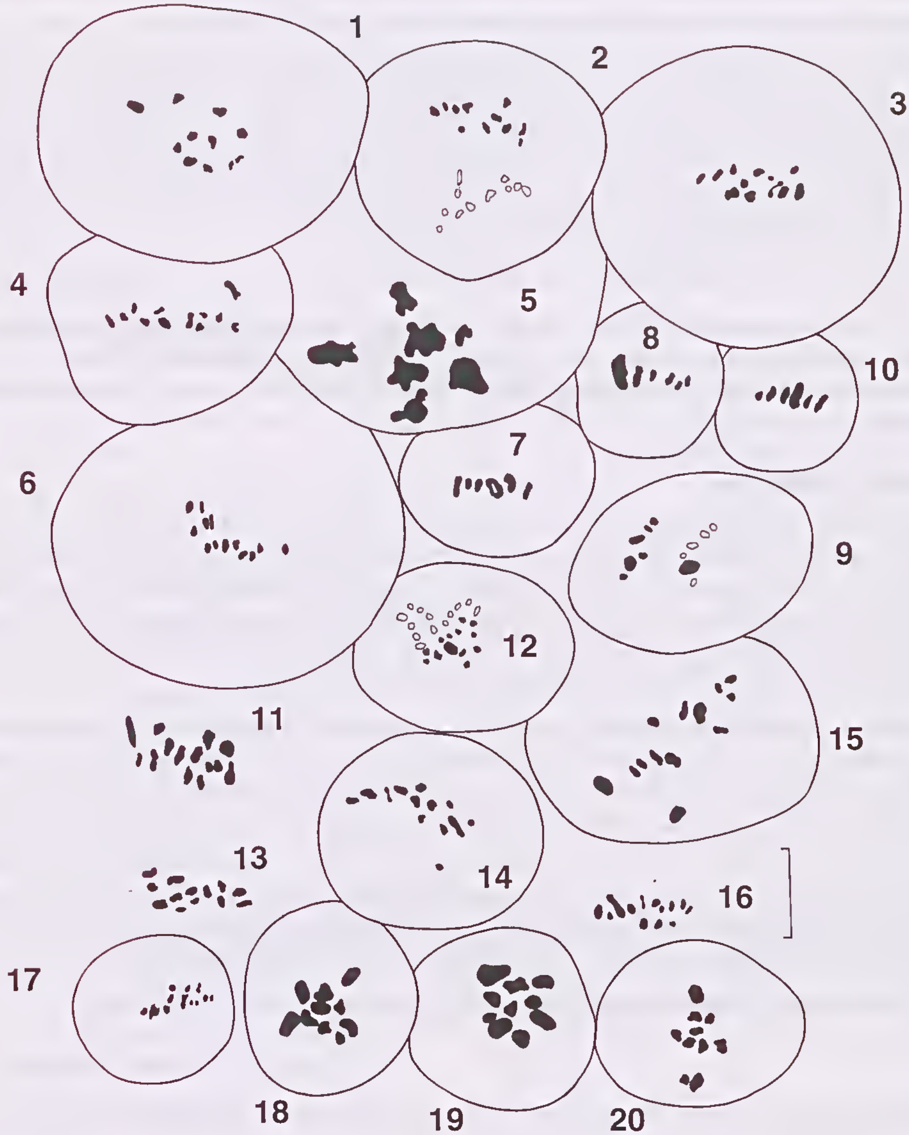

Fig. 2: 1–20. Chromosome numbers in Australian mosses (figures at Metaphase 1 of meiosis unless stated otherwise) — in families Cryphaceae (continued), Dicranaceae, Ditrichaceae, Daltoniaceae, Echinodiaceae. **1 & 2.** *Dendrocryphaea tasmanica* (continued) (*11/81*): **1.** n=11; **2.** Anaphase 1 with 11 half bivalents moving to each pole; **3 & 4.** *Dicranella dietrichiae*: **3.** (*24/79*) n=12; **4.** (*38/83*) n=12; **5.** *Dicranoloma dicarpum* (*56/81*) n=7; **6.** *Eccremidium pulchellum* (*7/77*) n=13; **7–12.** *Ceratodon purpureus*: **7.** (*56/83*) n=6; **8.** (*43/84*) n=6; **9.** (*43/84*) n=6 anaphase 1, with 6 half bivalents moving to opposite poles, note also the halves of one large bivalent are of unequal size; **10.** (*15/77*) n=6; **11.** (*48/82*) n=13; **12.** (*46/84*) n=13 anaphase 1- note the halves of the largest bivalent are unequal in size. **13–16.** *Ditrichum difficile:* **13.** (*10/87*) n=13; **14.** (*30/84*) n=13; **15.** (*59/82*) n=13; **16.** (*42/84*) n=13; **17.** *Achrophyllum dentatum* (*7/79*), fig. 115 in 1983c n=12; **18–20.** *Echinodium hispidum*:**18.** (*22/81*) n=10; **19.** (*18/81*) n=10; **20.** (*8/79*) n=10. Scale bar is 10 μm.

42/83) (Table 1). All had the chromosome number n=12 with normal meiosis thus supporting the original published number in Ramsay (1967, 1974).

The genus *Sclerodontium* (formerly known as *Dicnemoloma)* is represented in Australia by two species (Streimann & Klazenga 2002). In a collection of *S. pallidum* Ramsay (1977) reported the presence of enlarged sporocytes which appeared to be fused together and contained more than one nucleus with about 10% containing 5–8 spores, i.e. more than the normal 4 spores. These possibly represent aneuploid or polyploid spores but whether they would be viable is not known.

18. Sclerodontium pallidum (Hook.) Schwägr. n=11 no illustration

The chromosome number n=11 reported for *Sclerodontium pallidum (as Dicnemoloma pallidum)* in Ramsay (1967, 1974) is confirmed for an additional collection (*7/76*; Katoomba, Blue Mts, New South Wales, Table 1) in which meiotic behaviour was normal.

Family Ditrichaceae

The family Ditrichaceae includes 23 genera (Goffinet & Buck 2004) of which *Ditrichum, Ceratodon, Eccremidium* and *Pleuridium* are the main genera present in Australia. Chromosome numbers have been recorded previously for the Australian taxa *Ceratodon purpureus* n=13 and *Ditrichum difficile* n=13, 13+m (Ramsay 1974). There are no previous counts for *Eccremidium* while for *Pleuridium* the numbers n=7, 13, 26 are recorded (Fritsch 1991) although none are from Australia.

The chromosome numbers for the most well known and widespread species of *Ceratodon, C. purpureus* previously reported are n=11, 12, 13 with the most frequent being n=13 from Antarctica, Europe, India, Japan, North America, (Fritsch 1991, Goldblatt & Johnson 1994) and Australia (Ramsay 1974), while the number of n=6 (unpublished data from V.S. Bryan) is mentioned from Austria (Europe) for a single population in a discussion on mechanisms for variation in the species (Shaw & Beer 1999). All Australian material of *C. purpureus* belongs to the subspecies *convolutus* as recognised by Buck et al. (1990: 57) (refer to Streimann & Klazenga 2002).

19. Ceratodon purpureus (Hedw.) Brid subsp. ***convolutus*** (Reichardt) Burley
n=6 Figs 2.7–2.10
n=13 Figs 2.11 & 2.12

The identity of a number of additional collections of *Ceratodon purpureus* studied here was checked by R.D. Seppelt. Two different chromosome numbers were determined, n=6 and n=13. Three populations from localities widely separated in Australian Capital Territory, New South Wales (*56/83, 43/84*) and from Victoria (*15/77*) have the newly recorded chromosome number of n=6, representing the basic number for Ceratodon.. These complements included one larger somewhat dimorphic bivalent, the dimorphy being observed in the two half bivalents at anaphase I (Fig. 2.9).

Three other collections (*47/82, 48/82, 46/84*) from separate localities in New South Wales (Table 1) have the previously reported number n=13 (Ramsay 1967a, 1974). Evidence of possible dimorphy in the n=13 species is suggested in the anaphase I configurations where the largest half bivalent in one plate is larger than the equivalent one in the other plate.

The earliest records of cytology in *Ceratodon purpureus* by Shimotomi & Kimura (1934), in Japan and Jachimsky (1935) in Germany provided the chromosome number of n=13. They noted a large heteromorphic (dimorphic) bivalent at meiosis. In their studies of gametophytic mitosis and the karyotypes, Shimotomai & Kimura (1934) noted that a large metacentric member of the bivalent was present in the female complement (supported by Ramsay 1969) while the male equivalent was smaller. It was concluded that the differentiated chromosomes possibly represented X/Y sex chromosomes. Not everyone investigating this taxon has reached the same conclusion, nor has the largest bivalent always been recorded as heteromorphic. The sex of populations is not always cited but *Ceratodon purpureus* is usually considered to be dioicous.

These studies provide the first published illustrations of the chromosome number n=6 for *Ceratodon purpureus*. At metaphase 1 the largest bivalent is apparently dimorphic. Although the chromosome number n=12 has not been found, it can be surmised that autopolyploidy would result in the number n=12, and such plants would be expected to include some monoicous specimens. Based on Bryan's unpublished information of n=6 in a European collection, Shaw & Beer (1999) suggest that the derivation of the number n=13 in *Ceratodon purpureus* may result from autopolyploidy followed by subsequent aneuploidy. There are no illustrations for Bryan's chromosome record and no mention of a dimorphic bivalent.

DNA studies based on population genetic analyses using three unlinked loci to examine biogeographical patterns by McDaniel & Shaw (2005) showed that in *Ceratodon purpureus* "Australasian haplotypes were more closely related to northern hemisphere haplotypes than to haplotypes found in the equatorial regions. Collectively these data suggest that long distance migration within the northern hemisphere and Australasian regions is common (relative to mutation rate) and that migration between these two regions, potentially via equatorial populations, is more frequent than migration among equatorial populations".

The genus *Ditrichum* has been revised for Australia by Seppelt (1982, 1996) with eight species recognised. Previous chromosome number reports for 19 species from North America, India, and Europe in Fritsch (1991) and Goldblatt & Johnson (1994, 1996) are n=13 or 26 with a few having an additional 'm' chromosome. Records of n=13 are available for two species in New Zealand (Ramsay 2009) and n=13, 13+m for *D. difficile* in Australia (Ramsay (1967a, 1974).

20. Ditrichum difficile (Duby) M.Fleisch. n=13 Figs 2.13–2.16

Five additional collections of *Ditrichum difficile (59/82, 21/84, 30/84, 42/84, 10/87)* from several different localities in the Australian Capital Territory and New South Wales were examined. All had the chromosome number n=13, the same as previously recorded for this species by Ramsay (1967a, 1974).

There are six species of *Eccremidium* in Australia (Streimann & Klazenga 2002). No chromosome number has been reported previously for the genus.

21. Eccremidium pulchellum (Hook.f. & Wilson) Müll.Hal.
n=13 Fig. 2.6

In the collection of *E. pulchellum* from Victoria examined here (*7/77*) the chromosome number was determined as n=13.

Family Echinodiaceae

The Echinodiaceae is a small family with the single genus *Echinodium* occurring in Australia, New Caledonia and New Zealand. In Australia, *E. hispidum* occurs in the eastern states and also on Lord Howe Island where a second species is present.

The chromosome number for *E. hispidum* was incorrectly listed in Ramsay (1983c: 221) as n=9. The correct number n=10 was, however, reported in Ramsay (1983c: fig. 129) and Fritsch (1991).

22. Echinodium hispidum (Hook.f. & Wilson) Reichardt n=10 Figs 2.18–2.20

The previous report in Ramsay (1983c) did not include the locality. The data came from a collection (*18/79*) from Victoria (Sherbrooke Forest) and is supported here by three collections (*7/75, 18/81, 22/81*) from New South Wales.

Family Encalyptaceae

This is a small family of distinctive calcareous mosses containing the single genus *Encalypta*. Species occur in both the northern and southern hemispheres with 3 species recorded for Australia (Streimann & Klazenga 2002).

There are no previous chromosome number reports for *Encalypta* in Australia, although numbers recorded from various places in Europe include n=13, 26, 39 (Fritsch 1991).

23. Encalypta vulgaris Hedw. var. ***vulgaris*** n=13 Fig. 3.1

The number n=13 was determined in three collections (*17/80, 47/83, 48/83*) from two different localities in New South Wales (Table 1).

Family Fabroniaceae

In the family Fabroniaceae as recognised by Goffinet & Buck (2004), a group of epiphytic mosses, five of the genera occur in Australia. The chromosome number n=11 has already been recorded for three different species in the genus *Fabronia*, one each from India, Japan and Europe (Fritsch 1991)

In Australia *Fabronia* has four species, the most common and widely distributed being *F. australis*. The chromosome number of n=20 was reported by Ramsay (1967a, 1974) for this species.

24. Fabronia australis Hook.	n=30	Fig. 3.4
	n=20	Fig. 3.5
	n=11	Fig. 3.6

The chromosome number reported here for an additional population (*10/84*) of *F. australis* collected by Heinar Streimann from Queensland is n=20 and supports the earlier record by Ramsay (1967a, 1974). A second collection (*1/74*) from Moss Vale, New South Wales had the chromosome number n=30. In both cases, although the numbers are polyploid, meiosis was normal. In addition, a collection from Yarrangobilly(*19/80*) had the number n=11 as previously reported in northern hemisphere specimens (Fritsch 1991).

Family Fissidentaceae

Although the Fissidentaceae contains the single genus *Fissidens*, it is a large and universally distributed family of terrestrial mosses. In Australia it includes about 70 taxa

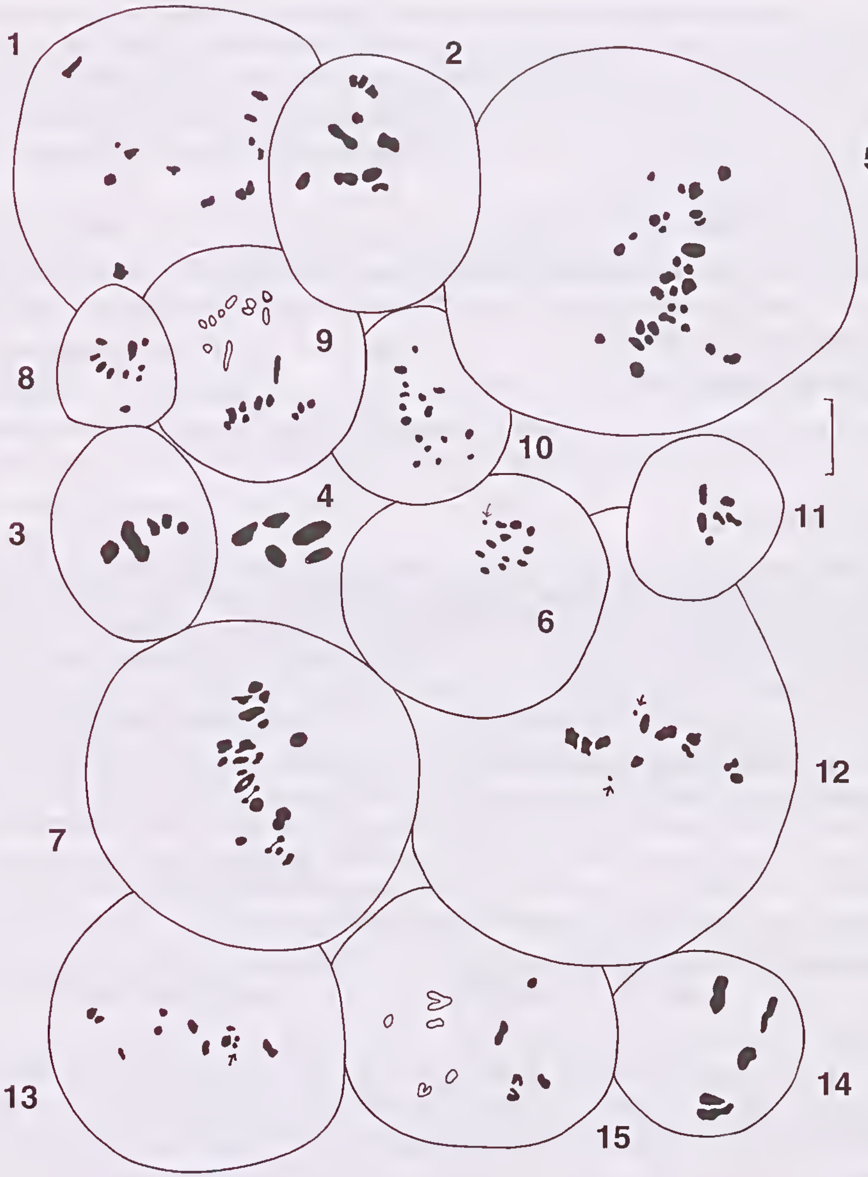

Fig. 3: 1–15. Chromosome numbers in Australian mosses (figures at Metaphase 1 of meiosis unless stated otherwise) – in families Encalyptaceae, Ptychomniaceae (Garovagliaceae), Fabroniaceae, Fissidentaceae Sematophyllaceae, Hedwigiaceae, Hypopterygiaceae. **1.** *Encalypta vulgaris* (*17/80*) n=13(12+m); **2.** *Garovaglia elegans* subsp. *dietrichiae* (*11/84*) n=10; **3 & 4.** *Euptychium cuspidatum* (*6/75*) n=5; **5–7.** *Fabronia australis:* **5.** (*1/74*) n=30; **6.** (*10/84*) n=20; **7.** (*19/80*) n=11; **8 & 9.** *Fissidens pallidus* (*5/79*): **8.** n=10; **9.** Anaphase 1 showing 10 half-bivalents moving to each pole; **10.** *Fissidens oblongifolius* (*16/79*) n=16; **11.** *Radulina borbonica* (*9/84*) n=6, note one bivalent is slightly smaller than others in the complement, but is not an m-chromosome in its relative size and behaviour; **12.** *Hedwigia ciliata* (*63/82*) n=11(10+m) note the m-chromosome (arrow); **13.** *Hedwigidium integrifolium* (*55/84*) n=11 (10+m) note m-bivalent separating (arrows); **14 & 15.** *Cyathophorum bulbosum* (*21/79*): 14. n=5; **15.** Anaphase 1, note five half-bivalents moving to opposite poles, one clearly larger. Scale bar is 10 μm.

with subspecies and varieties (Streimann & Klazenga 2002). There are chromosome reports for the genus from many parts of the world and numbers include n=5, 6, 8, 10, 12, 13, 16, 24. The low numbers n=5, 6, 8 are present with some intraspecific polyploids of these n=10, 12, 16, 24 (Fritsch 1991), indicating that polyploidy has played a role in the genus as it has in many other small colonising species such as the Pottiaceae. The most common number is n=12.

25. Fissidens pallidus Hook.f. & Wilson n=10 Figs 3.7 & 3.8

Ramsay (1967a, 1974) recorded the chromosome number n=13 for *F. pungens* and n=12 for *F. pallidus* from New South Wales. The number for the specimens of *F. pallidus* (*5/79*) examined here was n=10.

26 Fissidens oblongifolius Hook.f. & Wilson n=16 Fig. 3.9

This is the first chromosome record for *F. oblongifolius* and the number, obtained from a Victorian collection (*16/79*), is n=16.

Family Funariaceae

The family Funariaceae contains many small terrestrial mosses distributed worldwide. The stems are simple and some species are commonly associated with pots in glasshouses, e.g. *Funaria hygrometrica*. The family includes species with n=7, 14 but often species have high chromosome numbers, e.g. n=26, 27, 28, 45, 52, 54, 56 (Fritsch 1991) suggesting that polyploidy has played a significant role in evolution within this family of colonising mosses. The low count of n=7 for *Entosthodon wichurae* Fleisch. in India (Anand & Kumar cited by Fritsch 1991; Goldblatt & Johnson 2000) supports a basic number of x=7 for the genus, as proposed by Ramsay (1974). Fife (1985) revised the genera in the Funariaceae, and in discussing the phylogeny, refers to two main clusters of chromosome numbers — one with n=9 and its multiples and the other with n=14 (x=7) and multiples. The number n=26, present in a number of species, could be derived from n=7 or 9 by polyploidy followed by aneuploidy.

For Australia Fife & Seppelt (2001) recognised *Entosthodon* as including most species formerly in *Funaria*, while *Funaria hygrometrica* and F. *microstoma* are retained in the genus *Funaria*.

Chromosome numbers for some Australian Funariaceae were published in Ramsay (1974). These are *Entosthodon subnudus* (Hook.f. & Wilson) Fife var. *gracilis* (as *Funaria cuspidata* Hook.f. & Wilson) n=26; *Entosthodon muehlenbergii* (as *Funaria glabra* Taylor) n=52; and *Funaria hygrometrica* Hedw. n=28. Recently recorded chromosome counts for New Zealand collections by Ramsay (2009) are n=24 for *Entosthodon laxus* (*1/84*) and for two undetermined specimens of *Entosthodon* (*79/84*) n=18 and (*97/84*) n=26. The identity of the latter two has since been checked by Allan Fife and they have been determined as *Entosthodon laxus*, giving this species the three different numbers n=18, n=24 and n=26 in New Zealand.

Photomicrographs of the chromosome complement of *Entosthodon muehlenbergii* (as *Funaria glabra*) with a count of n=52+2m appear in Ramsay (1974: fig. 133) and with n=52 in Ramsay (1983c: fig. 36).

A count of n=21 was recorded from USSR by Lazarenko et al. cited in Fritsch (1991) for *Funaria hygrometrica*, a species in which the most frequent number is n=28 (Fritsch 1991). Recently n=21 has been reported for this species, possibly *F. hygrometrica* var.

calvescens, from Papua New Guinea (Ramsay 2008). The chromosome number n=26 was recorded for *Physcomitrium pyriforme* (as *P. conicum*) in Australia by Ramsay (1983c). Additional chromosome numbers are reported here for several species in the genus *Entosthodon*, for *Funaria hygrometrica* and one *for Physcomitrium.*

27. Entosthodon apophysata (Taylor) Mitt. n=24 Figs 4.2 & 4.3

Funaria. apophysata (Taylor) Broth. is synonymous with *Entosthodon apophysatus* (Fife & Seppelt 2001). The chromosome number determined here for two collections, one from Hamilton in Victoria (*6/77*) the other (*44/81*) from Queensland, is n=24 and they are the first reports for this species.

28. Entosthodon radians (Hedw.) Müll.Hal. n=52 Figs 4.7 & 4.8

A number of collections of this species (*8/76, 53/83, 3/87*) from various localities, Kuringai near Sydney, Dorrigo and Wauchope (New South Wales) and from Coolum (Queensland), all had the chromosome number n=52.

29. Entosthodon subnudus (Taylor) Mitt. var. ***gracilis*** (Hook.f. & Wilson) Fife n=26 Figs 4.5 & 4.6

This taxon now incorporates two former species of *Funaria, F. cuspidata* and *F. gracilis* (Fife & Seppelt 2001). The chromosome number n=26 has been reported previously for *Funaria cuspidata* in Ramsay (1974) and is recorded here for New South Wales collections of what would previously have been considered *Funaria gracilis* (*41/83*) from Woolgoolga and also *F. cuspidata* (*6/74, 27/81*) from Sydney.

A range of chromosome numbers n=14, 21, 28, 56 are recorded for the common weedy *Funaria hygrometrica*, from Europe, North America, India, Japan (Fritsch 1991) and n=28 for Australia (Ramsay 1974).

30. Funaria hygrometrica Hedw. n=28 Fig. 4.6

The chromosome number n=28, already determined for at least seven collections previously (Ramsay 1974), is confirmed here for a collection (*4/74*) from New South Wales, Kenthurst, Sydney and one (*1/77*) from Hamilton, Victoria.

In Australia, the genus *Physcomitrium* is represented by the single species *P. pyriforme* (syn *P. conicum*) (Fife & Seppelt 2001). Chromosome numbers recorded for *P. pyriforme* include n=9, 18, 26, 27, 36, 45, 52, 54 from various countries in Europe as well as India and U.S.A. (Fritsch 1991) with n=26 and 52 occurring most frequently in other species.

31. Physcomitrium pyriforme (Hedw.) Hampe n=26 Fig. 4.1

A collection of *P. pyriforme* from Australia was first published as *P. conicum* with the chromosome number n=26 in Ramsay (1983c: fig. 90) without locality data and voucher number. These are: *16/80*, Yarrongobilly Caves area, New South Wales. A count of n=26 was obtained here for an additional collection (*24/81*) from Wiangarie.

Family Grimmiaceae

The family Grimmiaceae contains 17 genera and is widespread in the world with *Grimmia* (13 species), *Schistidium* (5 species) and *Racomitrium* (11 species) occurring in Australia (Streimann & Klazenga 2002). Chromosome numbers are consistently n=13 with a few aneuploids of n=14 and polyploids n=26 for *Grimmia*; n=13, 14 and n=26 for *Schistidium apocarpum* in Europe, North America, New Zealand (Fritsch

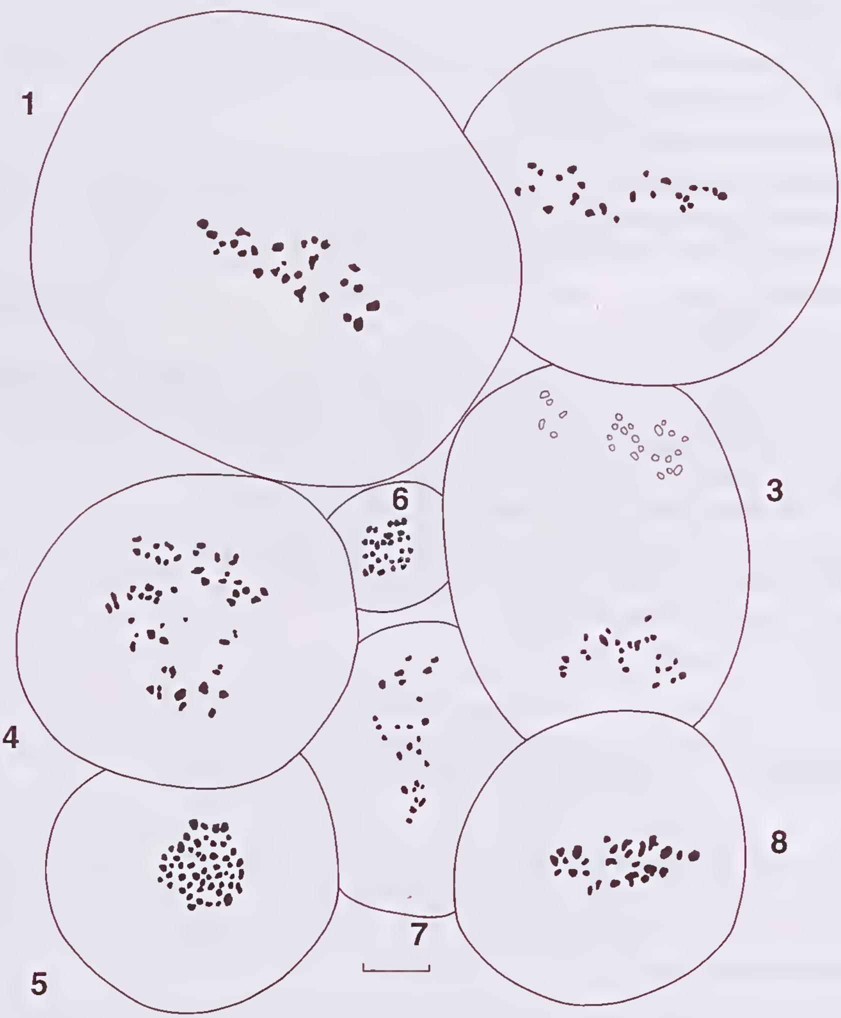

Fig 4: 1–8. Chromosome numbers in Australian mosses (figures at metaphase 1 of meiosis unless stated otherwise) — Funariaceae. **1.** *Physcomitrium pyriforme* (24/81) n=26. **2 & 3** *Entosthodon apophysatus* (6/77); **2.** n=24; **3.** Anaphase 1 note 24 half bivalents moving to each pole; **4.** *Funaria hygrometrica* (4/74) n=28; **5 & 6.** *Entosthodon subnudus* var. *gracilis*: **5.** (6/74) n=26; **6.** (41/83) n=26; **7 & 8.** *Entosthodon radians*: **7.** (3/87) n=52; **8.** (8/76) n=52. Scale bar is 10 μm.

1991, Goldblatt & Johnson 1994, Ramsay 2009). *Racomitrium* has the numbers n=7, 12, 13, 14 (Fritsch 1991). There are no previous counts for *Grimmia* or *Schistidium* in Australia but n=12, the most common number for the genus (Fritsch 1991) was reported for *R. crispulum* (Ramsay 1967a, 1974).

32. Grimmia pulvinata (Hedw.) Sm. var. ***africana*** (Hedw.) Hook.f. & Wilson n=26 Fig. 7.2

Previous chromosome numbers for *G. pulvinata* are n=10, 13, 14, 26, 26+m (Fritsch 1991) but none are for Australia or for the variety *africana*. The number obtained here is n=26 (*21/73*).

33. Grimmia trichophylla Grev. n=13 Fig. 7.1

The chromosome number n=13 has been recorded from Europe, and North America (Fritsch 1991) but no previous reports are available for *G. trichophylla* in Australia. The chromosome number is n=13 for one collection from New South Wales (*17/84*).

34. Schistidium apocarpum (Hedw.) Bruch. & Schimp. n=13 Fig. 7.3

The chromosome number in *Schistidium apocarpum* (*49/82*), was determined as n=13 and is the first report for this genus for Australia.

Family Hedwigiaceae

The Hedwigiaceae is a small family of mosses with five genera, of which, *Hedwigia* and *Hedwigidium* occur in Australia. The cosmopolitan species *Hedwigia ciliata* has been studied in Europe, U.S.A., India and Japan (n=11; Fritsch 1991, Goldblatt & Johnson 1994) and in Finland, Russia and Poland where polyploids with n=22 are reported (Kuta et al. 1990) but there are no previous reports for this species or any other in Australia.

35. Hedwigia ciliata (Hedw.) P.Beauv. n=11(10+m) Fig. 3.11

Australian populations from Bowral (*63/82*) and Wauchope (*39/83*) had the chromosome number n=11 (10+m) which includes an m-chromosome.

36. Hedwigidium integrifolium (P.Beauv.) Dixon n=11 Fig. 3.12

This is the first chromosome record for the genus *Hedwigidium*. The number n=11 in the collection (*55/84*) from the Australian Captial Territory is consistent with that recorded for *Hedwigia* but lacked the m-chromosome.

Family Hypnodendraceae

Hypnodendraceae, with the single genus *Hypnodendron*, has been studied cytologically by Ramsay (1974, 1983a, 1987) in Australia and New Zealand, two species from Papua New Guinea (*H. dendroides* & *H. diversifolium)* and one (*H. reinwardtii*) from Malaysia. The low number of n=4 has been recorded for several species of *Hypnodendron* (*H. comosum, H. comatum*, and *H. dendroides*). Of these, *H. comatum* and *H. comosum* occur in New Zealand, the latter also being present in southern temperate Australia. The tropical species, *H. dendroides* in Papua New Guinea, had a chromosome count of n=4 obtained as 2n=8 at premeiotic mitosis (Ramsay 1987). Other species had the number n=5 (3 species) or n=9 (5 species) (Ramsay 1987).

37. Hypnodendron comatulum (Geh. ex Broth.) Touw n=4 Fig. 5.10

This is the first chromosome record for *Hypnodendron comatulum,* an endemic species from northeast Queensland (Ramsay & Cairns 2004). The two collections studied here (*1/88, 2/88*) were obtained by Ilma Stone from Mt Bartle Frere. The sterile plants were maintained in covered dishes in the laboratory near a window until young shoots were produced and the apices harvested for chromosome counts. The chromosome number obtained was n=4. *Hypnodendron comatulum* belongs to the section *Comosa* (Touw 1971), the only one in which all species counted so far have the chromosome number n=4.

The chromosome complement of n=4 for *H. comatulum* lacks the small m-chromosome found in the complements of species with n=5 such as *H. diversifolium* from Papua New Guinea, with 2n=10 counted at premeiotic mitosis (Ramsay 1987: fig. 25) and *H. menziesii* n=5 (Newton 1973) from gametophytic mitosis from New Zealand. There are no previous reports of mitotic counts in species with the number n=4.

38. Hypnodendron vitiense Vitt var. ***australe*** Touw n=9 no illustration

The chromosome number of n=9 obtained here for *H. vitiense* (*2/87*) is from a different locality to previous counts: Cambewarra in New South Wales, and agrees with previous counts (Ramsay 1987).

Family Hypopterygiaceae

The present allocation of genera to the family that occur in Australia includes *Cyathophorum, Hypopterygium* and *Lopidium* (Goffinet & Buck 2004).

39. Cyathophorum bulbosum (Hedw.) Müll.Hal. n=5 Figs 3.13 & 3.14

An additional count for *Cyathorphorum bulbosum* from a population in Victoria (*21/79*) supports the previously recorded chromosome number n=5 (Ramsay 1967b, 1974) and is illustrated here at metaphase 1 and anaphase 1. Both Newton (1973) at mitosis and Ramsay (2009) at meiosis have reported n=5 for New Zealand specimens.

A world revision of the genus *Hypopterygium* has been published in recent years by Kruijer (2002) who also treated the genus for the *Flora of Australia* (Kruijer 2006). Several species of *Hypopterygium* recorded in Streimann & Klazenga (2002), including *H. rotulatum,* have been placed into synonymy with *H. tamarisci* (Krujer 2006). Earlier chromosome records of n=9, 18, c. 27, 36 have been reported for *H. rotulatum (=H. tamarisci)* in Ramsay (1967a) together with chromosome reports for material from Venezuela n=18, and for Japan n=9, 18 (Kruijer 2006). This species is widespread in pantropical and warm temperate regions of central and southern Africa, India, Asia north to Japan, central and South America, Australasia and Oceania with various growth forms recognised. Photomicrographs of the complement of *H tamarisci* (as *H. rotulatum*) were presented for populations with n=9 and n=36 in Ramsay (1983a: figs 40 & 41). The chromosome number n=6 has been recorded for both *H. didictyon* (as *H. novae-seelandiae)* by Newton (1973) from New Zealand and for *H. vreisii* from Papua New Guinea (Ramsay 2008).

40. Hypopterygium tamarisci (SW) Brid. ex Müll.Hal. n=9 Figs 5.1 & 5.2
n=18 no illustration

Collections studied in both new and previous accounts are all from New South Wales. Chromosome counts of n=9, 18, c. 27, 36 were reported by Ramsay (1967a) for a large

population of specimens all growing on a log more than 2 metres long across a stream at Mt Wilson in 1964. Unfortunately, the log and its mosses were washed away and the population destroyed in a snow storm several years later. However, collections made on the stream bank since then still include at least the chromosome numbers n=9 and n=18. Both these numbers are also reported here from Cambewarra n=9 (*1/75*) and n=18 (*3/75*).

The genus *Lopidium* is represented in Australia by two species (Streimann & Klazenga 2002). Previous chromosome counts are for two species, one from Japan with n=11 (Fritsch 1991) and one from Australia, *L. concinum*, with a count of n=12 (Ramsay 1974).

41. Lopidium concinum (Hook.) Wilson	n=12	Fig. 5.3
	n=c. 18 to 21	Figs 5.4 & 5.5
	irregular meiosis	Figs 5.6 & 5.7

A chromosome count of n=12 was obtained for some specimens from the collection (*14/79*) in which meiosis was normal. Others in the same collection (*14/79*) had capsules in which some sporocytes had normal meiosis and others had abnormal meiosis, indicating polyploidy. In these sporocytes, some apparently normal metaphase I plates indicated the count was n=c. 18–21, but in many cells there were both univalents and some multivalents, with at least two trivalents. This suggests that the plants might be triploids on a base of x=6, deduced for a count of n=18 since the original counts in Ramsay (1974) had n=12 chromosomes. Higher counts would indicate early separation of bivalents or failure to pair. There was also evidence of unequal distribution of chromosomes at anaphase I and laggards were often present at telophase I. Tetrads contained unequal numbers of spores, sometimes with laggards as well.

Family Lembophyllaceae

Five genera in the family Lembophyllaceae (Goffinet & Buck 2004) occur in Australia These include *Acrocladium, Camptochaete* and *Lembophyllum* for which chromosome counts have been obtained previously (Ramsay 1967a, 1974; Fritsch 1991). The genus *Camptochaete* was revised by Tangney (1997a), as was the rest of the family in Australasia (Tangney 1997b).

The genus *Acrocladium*, usually associated with the family Lembophyllaceae, has been placed in its own family (Klazenga pers. comm.) for the *Flora of Australia* upcoming second moss volume but is retained here at this stage. The only published chromosome count is n=11 (10+m) for *A. chlamydophyllum* from Australia (Ramsay 1967a, 1974).

42. Acrocladium chlamydophyllum	n=11(10+m)	Fig.5.8
(Hook.f. & Wilson) Müll.Hal. & Broth.	n=20	Fig. 5.9

The chromosome count of n=11(10+m) obtained here from Tasmania and Victoria (*53/81, 58/81*) confirms the original count, while a count of n=20 for another collection (*49/81*) indicates polyploidy. Meiotic behaviour in these capsules was regular with no sign of multivalents or irregular division.

In Australia the genus *Camptochaete* is represented by 6 species (Tangney 1997a, b; Streimann & Klazenga 2002). To reflect nomenclatural changes, *C. ramulosa*=*C. deflexa* (Wilson) A.Jaeger with the numbers n=10, 11, 22 and *C. vaga*=*C. excavata* (Taylor) A.Jaeger n=11 for reports in Ramsay (1967a, 1974).

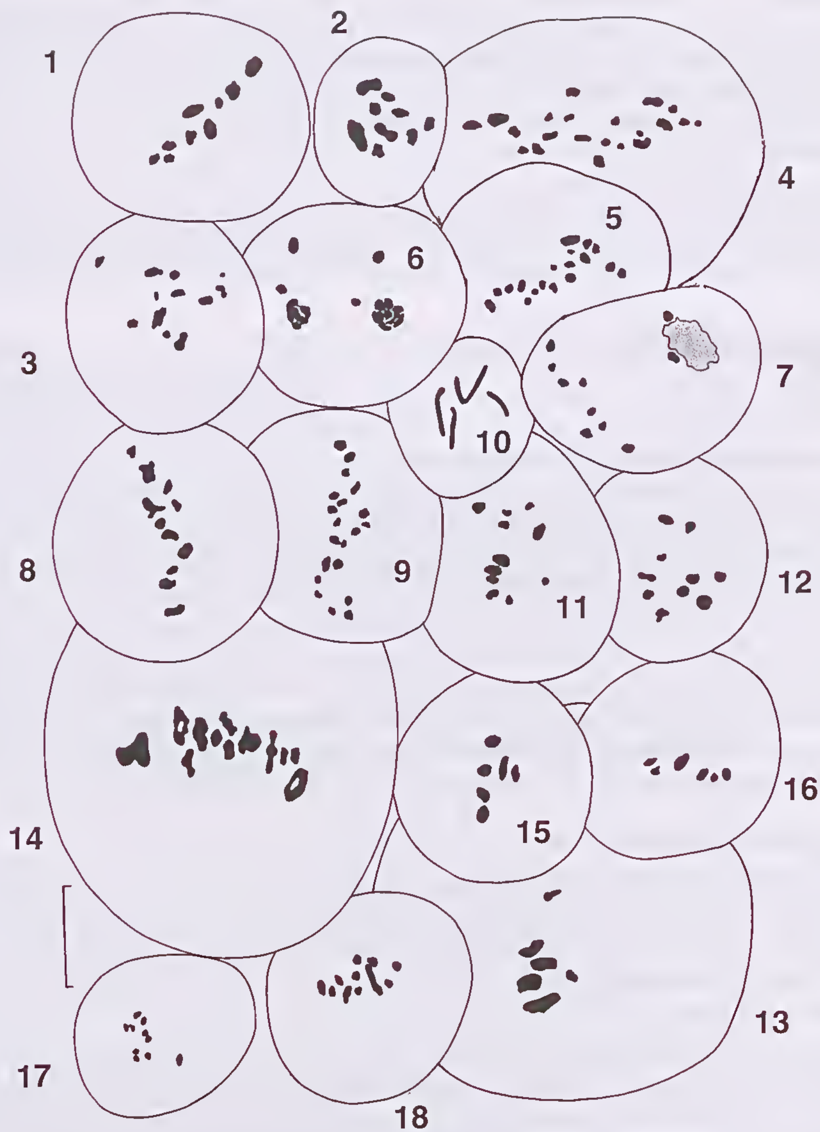

Fig. 5: 1–18. Chromosome numbers in Australian mosses (figures at Metaphase 1 of meiosis unless stated otherwise) — in families Hypopterygiaceae (contd), Hypnodendraceae, Lembophyllaceae, Leptostomaceae, Leucobryaceae, Mitteniaceae, Meteoriaceae. **1 & 2.** *Hypopterygium tamarisci*: **1.** (*4/72*) n=9; **2.** (*3/75*) n=9; **3–7** *Lopidium concinnum*; **3.** (*14/79*) n=12; **4 & 5.** polyploids (*14/79*) **4.** n=22; **5.** n=18; **6 & 7.** (*14/79*), meiotic irregularities **6.** misdivisions at Metaphase 1 to Anaphase 1, note most half bivalents grouped together except for two towards each pole; **7.** misdivisions at Anaphase 1 to Telophase 1, note eight half bivalents at one pole, at other end all clumped except for two; **8 & 9.** *Acrocladium chlamydophyllum*: **8.** (*53/81*) n=11; **9.** (*49/81*) n=20; **10.** *Hypnodendron comatulum* (*2/88*) n=4 gametophytic mitotic chromosomes; **11.** *Camptochaete arbuscula* var. *arbuscula* (*29/83*) n=11; **12.** *Lembophyllum clandestinum* (*17/79*) n=10; **13 & 14.** *Leptostomum erectum*: (*2/76*) **13.** n=12; **14.** n=6; **15 & 16.** *Leucobryum aduncum* var. *scalare* : **15.** (*13/75*) n=6; **16.** (*14/81*) n=6; **17.** *Mittenia plumula* (*22/79*) n=10; **18.** *Papillaria crocea* (*46/83*) n=11, note large rod shaped bivalent. Scale bar is 10 µm

43. Camptochaete arbuscula (Sm.) Reichardt var. ***arbuscula*** n=11 Fig. 5.11

Three separate collections (*19/77, 29/83, 35/83*) had the chromosome number n=11, a number common to all three species examined so far in Australia.

A recent review of the genus *Lembophyllum* (Tangney 2008) recognises two separate species — *L. divulsum* and *L. clandestinum*. Previously these two species have been treated as varieties of the single species *L. divulsum* by Sainsbury (1948), Scott & Stone (1976) and Fife (1995) for Australasia.

44. Lembophyllum clandestinum (Hook.f. & Wilson) Wijk & Margad.
n=10 Fig. 5.12

The chromosome count of n=10 obtained here in an additional three collections, one from Wilson R., New South Wales (*3/86*) and two others (*30/77, 17/79*) representing the first records from Victoria, agree with the previous count published as *L. divulsum* var. *clandestinum*.

Family Leptostomaceae

The family Leptostomaceae contains the single genus *Leptostomum* distributed in Australia, New Zealand and Papua New Guinea. Previous chromosome records are n=6, 12 for *L. inclinans* in Australia (Ramsay 1967a, 1974) and n=6 for *L. inclinans* in New Zealand (Ramsay 2009).

45. Leptostomum erectum R.Br. n=6 Fig. 5.13
n=12 Fig. 5.14

This is the first chromosome report for the species *L. erectum* from New South Wales. The two numbers n=6 and n=12 are recorded for different specimens in a collection from the Blue Mts (2/76). Both these numbers have previously been recorded for *L. inclinans* (Ramsay 1974).

Family Leucobryaceae

As presently recognised by Goffinet & Buck (2004) there are 10 genera in the family Leucobryaceae, including *Campylopus* and *Leucobryum,* that occur in Australia. Chromosome records for *Campylopus* include n=10, 11, 12, 13, 15, c. 18 with n=13 for *C. introflexus* for Australia (Ramsay 1967a, 1974). For *Leucobryum* the numbers recorded are n=6, 11, 13, 14 for several species in the northern hemisphere - U.S.A., Europe, Japan, and China (Fritsch 1991; Goldblatt & Johnson 1994, 1996, 2003, 2006), n=10 for *L. sanctum* and *L. javense* from Papua New Guinea (Ramsay 2008).The number n=6 was reported for *L. albidum* by Anderson & Bryan (1958) but Mehra & Khanna (1961) questioned the number as the meiotic configurations seemed unusual. However, Przywara et al. (1983) recorded n=6 for *L. glaucum* in Poland while n=11 has been found for this species in other parts of Europe (Fritsch 1991). The most frequent chromosome number recorded for species studied so far is n=11.

N. Klazenga, who has been studying the genus for the *Flora of Australia*, has checked the names of specimens examined here.

46. Leucobryum candidum (Brid. ex Beauv.) Wilson n=11 no illustration

A previous count of n=11 for three populations named as *L. candidum* var. *pentastichum* (Dozy & Molk.) Dixon was published by Ramsay (1967a, 1974). Additional collections examined here (*5/72, 1/73*) also had n=11.This variety has been placed into synonymy

with *L. aduncum* var. *aduncum* by Yamaguchi (1993) and Klazenga (pers. comm.) is still considering whether *L. candidum* may be synonymous with *L. aduncum*.

*47. **L. aduncum*** Dozy & Molk var. ***scalare*** (Müll.Hal. ex M.Fleisch.) A.Eddy n=6 Figs 5.15 & 5.16

This study provides the first chromosome records for this taxon with a count of n=6 for two collections from New South Wales (*13/75*, *14/81*) and one from Victoria (*19/79*) and adds a third species to the list in *Leucobryum* with the number n=6, suggesting this is probably the basic number for the genus.

Family Meteoriaceae

Australian members of the family Meteoriaceae were revised by Streimann (1991, 1992). As presently recognised, there are 22 genera excluding *Papillaria* (Goffinet & Buck 2004) of which six, (seven including *Papillaria),* are recorded for Australia.

Papillaria was synonymised with *Meteorium* by Buck (1994: p. 61), but this has not been accepted yet for Australian species. Streimann, who revised the Australian species, although agreeing to some extent with Buck, retained *Papillaria* as there are no appropriate combinations for these species in *Meteorium* (Streimann & Klazenga 2002). Chromosome records for the family are n=11 or n=11, 22 for three species of Papillaria from Australia (Ramsay 1967a, 1974), with n=9, 10 for three species from India. In addition n=10 is reported for some species of *Meteorium* from Japan, and n=11 for species of *Meteoriopsis* from Japan and India (Fritsch 1991, Goldblatt & Johnson 1998).

*48. **Papillaria crocea*** (Hampe) A.Jaeger n=11 Fig. 5.18

This report of the chromosome number n=11, the first for the species *P. crocea,* agrees with that so far recorded for three other species *P. amblyacis, P. flavolimbata*, and *P. flexicaulis* (Ramsay 1974). The collection (*40/83*) came from Wauchope, New South Wales and was collected with W.B. Schofield.

Family Mitteniaceae

The Mitteniaceae is a small monotypic Australasian family of mosses with a specialised perennial luminescent protonema and unique peristome structure (Stone 1961b). The chromosome number of n=10 was recorded for *M. plumula* from Australia (Ramsay 1983c fig 109) without the chromosome voucher number and locality data.

*49. **Mittenia plumula*** (Mitt.) Lindb. n=10 Fig 5.17

The drawing of the Ramsay (1983c) specimen (*22/79*, Sassafras Creek, Victoria) is included here for easy comparison with other taxa.

Family Mniaceae

The Mniaceae is a largely northern hemisphere family with 15 genera including *Pohlia* and *Schizymenium* recently transferred from the family Bryaceae by Goffinet & Buck (2004). There have been extensive studies of the chromosomes in a number of genera, including karyotypes of mitotic complements as well as heterochromatin properties summarised in Newton (1986). For *Mnium* and *Plagiomnium* the recorded chromosome numbers for various species in the northern hemisphere are n=6, 7, 8, 12 14 with many examples of karyotypes (Fritsch 1991) and n=14 for one species of

Orthomnion. For *Pohlia*, numbers recorded are n=10, 11, 13, 14, 22, 33 and 40 while a range of numbers, n=11, 20, 22, 33, the most frequent number being n=22, are recorded for the single species *P. nutans* from the northern hemisphere, particularly Europe and North America (Fritsch 1991). Ramsay & Spence (1996) record n=22 for *P. nutans* in Australia. The chromosome number for *Mielichhoferia*, which has been synonymised with *Schizymenium*, is n=10 (Goldblatt & Johnson 1994).

Previous counts for various *Plagiomnium* species from many regions, e.g. Europe, Japan, North America and India, China, Papua New Guinea (Fritsch 1991; Goldblatt & Johnson 2003, 2006; Ramsay 2008) include n=6, 7, 8, 12, 14 sometimes with both n=6 & 7 or n=6 & 12, 7 & 14 occurring in the same species. While the number n=6 occurs in *Plagiomnium affine*, a series of counts n=6, 7, 12 and 18 have been reported by Klos et al. (2001) who noted that specimens of one variety had the number n=6 plus 2, 3 or 4 m-chromosomes.

50. Plagiomnium novae-zealandiae (Colenso) T.J.Kop. n=14 Fig. 7. 20

This is the first chromosome number recorded for *Plagiomnium novae-zealandiae*, a species which occurs in Australia and New Zealand. The specimen studied (*4/88*), came from the Jenolan Caves area in New South Wales. The n=14 chromosomes, examined at gametophytic mitosis, are varied in size and shape but some appear as pairs, suggesting a polyploid origin.

Family Neckeraceae

Eight, mainly tropical, genera in the family Neckeraceae occur in Australia, including *Neckera, Homaliodendron, Touwia, Neckeropsis* and *Thamnobryum*. Chromosome numbers recorded in Fritsch (1991) are n=10, 11 for three species of *Homaliodendron* from India and Japan, n=10, 11, 12 for *Neckera* spp. from Europe and Japan and n=10 for *Neckeropsis* from Japan while n=11, 22 have been reported for *Thamnobryum* species from Japan, Europe (Fritsch 1991).

The genus *Thamnobryum* has three species in Australia with counts of n=11 for *T. pandum* (Ramsay 1967a, 1974) and n=11 (10+m) for *T. pumilum* (Ramsay 1983c: fig.119).

51. Thamnobryum pumilum (Hook.f. & Wilson) Nieuwl.

n=11(10+m) no illustration

This chromosome record of n=11(10+m) from The Big Scrub, a remnant of tropical rainforest in north-eastern New South Wales (*45/83*) confirms that reported in Ramsay (1983c: fig. 119) from Mt Wilson, New South Wales (*24/64*).

Family Orthotrichaceae

Previous chromosome studies on various genera in the family Orthotrichaceae have been published in Ramsay (1966, 1974, 1979, 1984, 2007), Ramsay & Lewinsky (1984), Ramsay & Vitt (1986), Ramsay & Bergstrom (1995), Ramsay et al. (1995) for a number of species from Australia, New Zealand, Heard Island and Papua New Guinea.

52. Orthotrichum tasmanicum Hook. f. & Wilson var. ***tasmanicum***

n=6 no illustration

Additional chromosome counts for *O. tasmanicum* (Table 1) are noted here for two collections, one from the Australian Captial Territory (*9/87*) and one from Jenolan

Caves, New South Wales (*6/88*). The chromosome number of n=6 agrees with previous counts for this species and is not illustrated here.

Family Pottiaceae

Genera in the very large family Pottiaceae were revised by Zander (1993) with many name changes but a number of Australian taxa were not examined in detail. Revisions are presently in progress for this family in the *Flora of Australia* so names in Streimann & Klazenga (2002) are accepted here until the new work is published. Of the genera now recognised by Goffinet & Buck (2004) some, such as *Barbula, Ephemerum, Tortella, Tortula, Syntrichia, Trichostomum, Weissia* contain a number of species in Australia which have been studied cytologically. However, the unique small genera *Phascopsis, Stonea, Uleobryum* which were described by Stone (1980, 1989, 1984) with additional data in Jolley & Milne (2007) have not yet been examined. The family is noted for the many taxa with high chromosome numbers and a range of numbers within species.

In Australia, *Aloina* is a genus with three species (Streimann & Klazenga 2002). Chromosome numbers for this genus are generally high n=24, 26, 28, 48 although one count for *A. rigida* is n=12 from Poland (Kuta et al. 1995). Records from overseas include n=26 for *Aloina aloides* from Great Britain (Fritsch 1991) and n=24 for *A. aloides* var. *ambigua* from Europe and U.S.A.

53. Aloina aloides (Schultz) Kindb. var. ***ambigua*** (Bruch & Schimp.) E.J.Craig.
n=26 Fig. 6.1

The specimens of *A. aloides* var *ambigua* studied here were collected by W.B. Schofield at Marulan, New South Wales (*27/83*). The chromosome number obtained is n=26 which matches the number for *A. aloides* but the number for var. *ambigua* has been recorded as n=24 in previous studies overseas (Fritsch 1991).

Barbula is a large genus distributed worldwide with the chromosome numbers n=7, 11, 12, 13, 14, 24, 26 recorded from North America, India China, Japan, (Fritsch 1991, Goldblatt & Johnson 1994).There are 17 species recognised for Australia (Streimann & Klazenga 2002) of which at least seven are considered endemic. The genus is at present under review for the *Flora of Australia.* Some species previously named as *Tortella* are now in synonymy with *Barbula* (Zander 1993), including the Australian species *Tortella calycina=Barbula calycina.* There are possibly four Australian species retained in the genus *Tortella* (Streimann & Klazenga 2002) but no previous chromosome number reports for any of them. The low number n=7 has been published for one species of *Tortella* from Europe (Fritsch 1991, Goldblatt & Johnson 1996) while numbers previously recorded for species from North America and Europe (Fritsch 1991) are n=13, 13+m, 14, 15, 30, 52. Australian chromosome records published for *Barbula calycina* n=13, 30, 52 were reported as *Tortella calycina* by Ramsay (1967a, 1974).

54. Barbula calycina Schwägr. n=13 Figs 6.3–6.5

Additional chromosome number reports for *Barbula calycina* (*9/73, 3/74, 29/79, 31/83, 43/83*) confirm the number n=13 and represent collections from several different localities in New South Wales (Table 1).

Several species of *Bryoerythrophyllum* from India had the chromosome number n=13 (Goldblatt & Johnson 1994, 2003) but there are no previous records from Australia.

55. Bryoerythrophyllum dubium (Schwägr.) P.Sollman n=13 Fig. 6.2

In *Bryoerythrophyllum*, the Australasian species *B. binnsii* (R.Br.Ter.) Dix., has been placed into synonymy with the more widespread species *B. dubium* (Schwägr.) Sollman (Sollman 2002).The chromosome number n=13 was determined for one collection (*57/83*) from Goulburn, New South Wales.

The genus *Gymnostomum* has only the one species, *G. aeruginosum*, listed for Australia (Streimann & Klazenga 2002). *Gymnostomum aeruginosum* and *G.calcareum* are considered conspecific by Zander (1977: 259) but not by Catcheside (1980) or Catcheside & Stone (1988) who retain them as separate species. Previous chromosome counts for three species in the genus from U.S.A., Europe and India are all n=13 (Fritsch 1991).

56. Gymnostomum calcareum Nees & Hornsch. n=13 no illustration

This is the first chromosome number reported for an Australian population of *G. calcareum*. The collection examined here (*53/84*) from the Coorong in South Australia had the chromosome number n=13.

There are no previous chromosome counts for the genus *Tetrapterum*, a genus with five recorded species for Australia (Streimann & Klazenga 2002).

57. Tetrapterum cylindricum (Taylor) A.Jaeger n=26 Fig. 6.17

The chromosome number of n=26 reported here in two separate collections (*14/77*, *23/81*), suggests a polyploid origin and the normal meiotic behaviour supports established allopolyploidy.

58. Tortella knightii (Mitt.) Broth. n=13 Figs 6.6 & 6.7
n=20 Fig. 6.8

These are the first chromosome number records for *Tortella knightii*, a species distributed in New South Wales, Victoria and Tasmania. One collection studied here (*20/84*) had the chromosome number n=13, while two others (*52/83*, *18/87*) had the number n=20. All were collected in the Blue Mountains, New South Wales.

In Australia, 21 species are listed for *Tortula* in Streimann & Klazenga (2002). Many of these were cited as *Syntrichia* in Zander (1977) but are under review for the *Flora of Australia*. Chromosome numbers recorded worldwide for the large genus *Tortula* are varied and include n=7 (6+m), 7, 12, 13, 24, 26, 30, 36, 40, 44, 48, 50, 52, 60, 66. The high numbers indicate a high degree of polyploidy for a number of species such as *T. muralis*, *T. subulata*, *T. mucronifolia* (Fritsch 1991, Goldblatt & Johnson 2003).

Previously recorded chromosome numbers for Australian species are n=48 for *T. andersonii* (as *T. bealeyensis*); n=7 (6+m), and n=12 for *T. papillosa* and n=48 for *T. muralis*. (Ramsay 1967a, 1974). The identity of the collections of *T. brevisetacea* from New Zealand (n=26; Ramsay 2009), is corrected here to *T. antarctica*, the same number as Australian reports below.

59. Tortula andersonii Åongstr. n=14 Fig. 6.13
n=22 Fig. 6.12

In addition to the previous report of n=48 (Ramsay 1974, as *T. bealeyensis*) two different

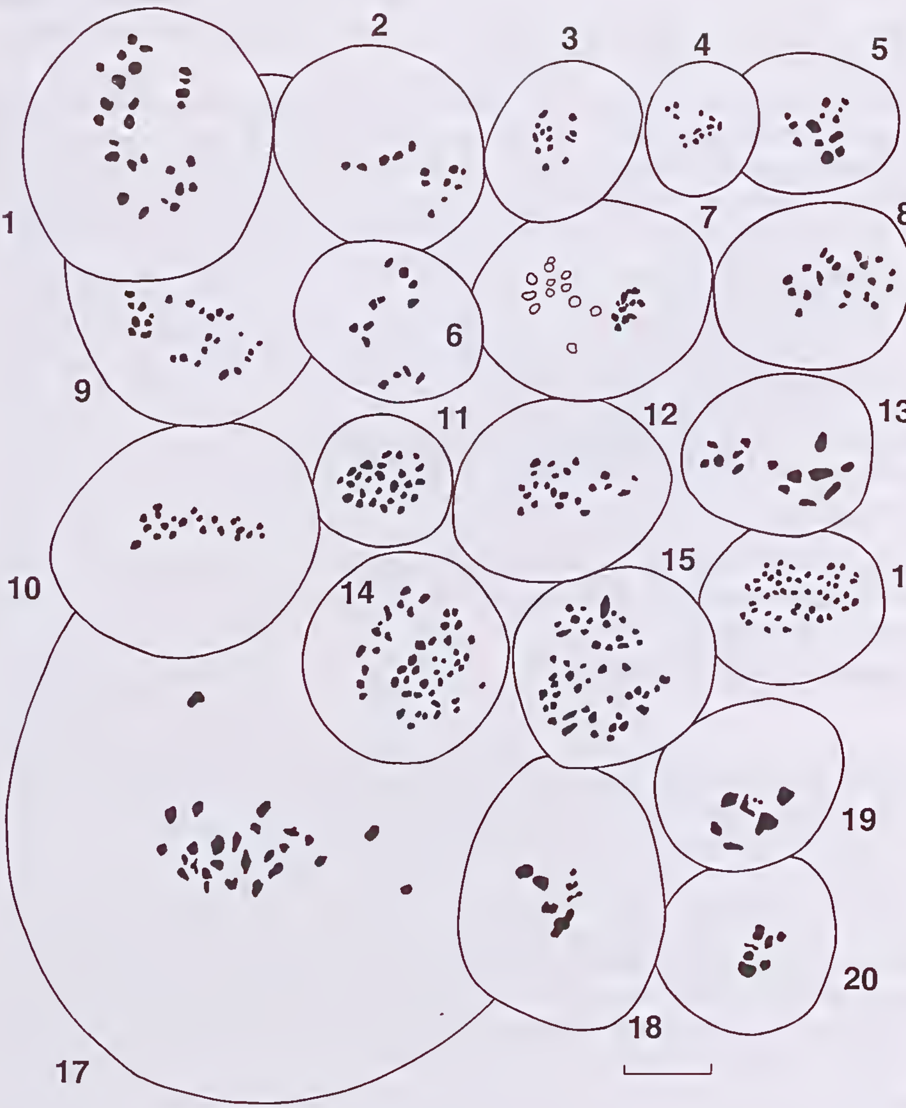

Fig. 6: 1–20. Chromosome numbers in Australian mosses (figures at metaphase 1 of meiosis unless stated otherwise) — in family Pottiaceae. **1.** *Aloina aloides* var. *ambigua* (*27/83*) n=26; **2.** *Bryoerythrophyllum dubium* (*57/83*) n=13; **3–5** *Barbula calycina*: **3.** (*40/83*) n=13; **4.** (*43/83*) n=13; **5.** (*29/79*) n=13; **6 & 7.** *Tortella knightii* (*20/84*): **6.** n=13; **7.** Anaphase 1; **8.** *Tortella knightii* (*18/87*) n=20; **9.** *Tortula truncata* (*12/77*) n=26; **10.** *Tortula atrovirens* (*48/84*) n=21; **11.** *Tortula antarctica* (*35/84*) n=26; **12 & 13.** *Tortula andersonii* (*46/82, 46/82a*): **12.** n=22; **13.** n=14; **14–16.** *Tortula muralis*: **14.** (*28/73*) n=48; **15.** (*30/79*) n=48; **16.** (*13/77*) n=48; **17.** *Tetrapterum cylindricum* (*23/81*) n=26; **18–20.** *Tortula papillosa*: **18.** (*25/81*) n=7 note the m-bivalent; **19.** (*42/82*) n=7; m-bivalent separating; **20.** (*58/82*) n=7. Scale bar is 10 µm.

chromosome numbers, n=14 and n=22, have been recorded for *T. andersonii* (*46/82*, *46a/82*) from the Yarrangobilly Caves area.

60. *Tortula antarctica* (Hampe) Wilson n=26 Fig. 6.11

The chromosome number reported here for *T. antarctica* is n=26 (Table 1) for two collections, from widely separate localities: - one (*35/84*) from Port Macdonald in South Australia, the other (*16/87*) from Jenolan Caves, New South Wales, are the first Australian records for this species.

61. *Tortula atrovirens* (Sm.) Lindb. n=21 Fig. 6.10

Previous chromosome counts for *T. atrovirens* (as *Desmatodon convolutus* (Brid.) Grout) in Europe are n=26 and for other species in North America and Europe n=13, 26, 39 and 52 (Fritsch 1991). The number reported here, the first for Australia (*48/84*) is n=21 from Culcairn in New SouthWales.

62. *Tortula muralis* Hedw. n=48 Figs 6.14–6.16
n=24 no illustration

The species *T. muralis* is variable and cosmopolitan. Various chromosome numbers, n=14, 24, 26, 48, 52, 66, have been recorded for *T. muralis* in the northern hemisphere (Fritsch 1991), with n=48 for Australian populations. (Ramsay 1983c: fig 39, photomicrograph). Five additional collections (*28/73*, *13/77*, *21/77*, *30/79*, *3/91*) from various locations in Victoria and New South Wales all have the chromosome number n=48 while two separate collections from Echo Point, New South Wales had different numbers: n=48 (*28/73*) and n=24 (*25/73*).

63. *Tortula papillosa* Wilson n=7 (6+m) Figs 6.18–6.20

Previous chromosome numbers recorded for *Tortula papillosa* are n=7 (6+m), 12 (Ramsay 1967, 1974). In these studies the number n=7 is recorded for three additional populations (*25/81*, *42/82*, *58/82*) (Table 1) from New South Wales.

64. *Tortula truncata* (Hedw) Mitt. n=26 Fig. 6.9

This species was formerly known as *Pottia truncata* but was reassigned to *Tortula* by Zander (1977). The numbers n=20, 25, 26, 52 have been reported in Fritsch (1991) from Europe for *Pottia truncata*. The collection studied here (*12/77*) has a count of n=26 and is the first chromosome report for this species from Australia.

65. *Weissia brachycarpa* (Nees & Hornsch.) Jur. n=12 Fig. 7.4

Weissia brachycarpa differs from *W. controversa* in having broad, plane-margined leaves and is gymnostomous.The collection studied (*42/83*), with a count of n=12, is the first chromosome number record for *W. brachycarpa*.

66. *Weissia controversa* Hedw. n=13 Figs 7.5–7.7

Previous information on *Weisia controversa* (Ramsay 1974) provided the chromosome number n=13 which is confirmed here for an additional three collections (*5/74*, *9/76*, *13/84*) all from New South Wales (Table 1).

Ptychomniaceae

The current concept of Ptychomniaceae(Buck & Goffinet 2000, Goffinet & Buck 2004) includes 10 genera. Of these, the following six are present in Australia- *Ptychomnion, Euptychium, Garovaglia, Glyphothecium, Hampeella, Tetraphidopsis.* All,

except *Euptychium* and *Garovaglia* which are tropical to subtropical in distribution, are temperate taxa. Chromosome numbers are now available for all genera except *Tetraphidopsis*. The genera *Ptychomnion* and *Glyphothecium* have a count of n=7 (Ramsay 1967a, 1974) and n=7 has also been reported recently for two other genera in this family from New Zealand that are not present in Australia, *Cladomnion* and *Dichelodontium* (Ramsay 2009). Other published data give different numbers:, e.g. *Garovaglia* n=10 for two species in Papua New Guinea (Ramsay 2008) and n=10 for *Euptychium robustum* on Lord Howe Island (Ramsay 1992). *Garovaglia* and *Euptychium* were formerly in the family Garovagliaceae. Here chromosome numbers are published for the first time for *Hampeella*, *Euptychium* and *Garovaglia* for mainland Australia.

67. Euptychium cuspidatum (Mitt.) Mitt. n=5 Fig. 4.3

There are four species of *Euptychium* listed in Streimann & Klazenga (2002) for Australia, of which two species are present only on Lord Howe Island, one of which, *E. robustum* has n=10 (Ramsay 1992). The collection studied here (*6/75*) from Coffs Harbour, New South Wales had the chromosome number n=5. This is half the number published for *E. robustum* and may represent the basic number for the genus.

68. Garovaglia elegans (Dozy & Molk.) Hampe ex Bosch & Sande Lac. subsp. *dietrichiae* (Müll.Hal.) During n=10 Fig.4.2

In Australia, two species of *Garovaglia* are recognised (Streimann & Klazenga 2002), occurring only in the rainforests of northeastern Queensland and northern New South Wales. The collection of *G. elegans* subsp. *dietrichiae* studied here (*11/84*) from Atherton, Queensland had the chromosome number n=10 which corresponds to that for two other species examined in Papua New Guinea (Ramsay 2008).

The genus *Glyphothecium* is distributed in Southeast Asia and New Zealand as well as temperate eastern States in Australia.

69. Glyphothecium sciuroides (Hook.) Hampe n=7 no illustration

Previously, the chromosome number n=7 for *Glyphothecium sciuroides* was obtained for Australian specimens by Ramsay (1967a) and illustrated in Ramsay (1974) as well as for New Zealand (Ramsay 2009). The collection studied here from New SouthWales (*50/84*) confirms the number as n=7.

70. Hampeella pallens (Sande Lac.) M.Fleisch. n=6 Figs 7.8–7.10
n=12 Fig.7.11

The genus *Hampeella*, is an epiphytic moss with two species distributed in eastern Australia and New Zealand. Scott & Stone (1976) describe *H. pallens* noting that sporophytes are present in Queensland specimens but rare in New South Wales. However, in the collections studied here from New South Wales and in others we have found, sporophytes are fairly common, e.g. from the Blue Mountains. The specimens studied here were from northern New South Wales and the Queensland/New South Wales border area.

These are the first chromosome number reports for *Hampeella*. In three populations studied (*33/81*, *50/83*, *60/84*) the chromosome number was n=6 while another population (*49/83*) had the chromosome number n=12 representing a polyploid based on n=6.

A single species of *Ptychomnium* occurs in Australia, including Lord Howe Island, as well as New Zealand. A second species is present on Macquarie Island and New Zealand.

71. Ptychomnium aciculare (Brid) Mitt. n=7 Fig. 7.12

The chromosome number n=7 was found in all specimens of *Ptychomnion aciculare* examined for mainland Australia, Lord Howe Island and New Zealand (Ramsay 1974, 1992, 2009). This is the first chromosome number report from Tasmania (*59/81*; n=7) and agrees with former counts. Two additional counts from mainland Australia examined here also had the chromosome number n=7.

Racopilaceae

The Racopilaceae is a small family with only two genera *Powellia* and *Racopilum*, both being represented in Australia (Zanten 2006a, b). There are no chromosome records for *Powellia*, but for *Racopilum* the numbers n=10, 20 and 21 are recorded (Fritsch 1991). Of these n=10 is most frequent and has been reported for R. *convolutaceum* (=*R. cuspidigerum* var *convolutaceum*) in Australia, *R. cuspidigerum* from Borneo, of *R. spectabile* from Papua New Guinea (Ramsay 2008), *R. capense* from Tanzania, and *R. strumiferum* in New Zealand (de Vries et al. 1989). *Racopilum tomentosum* from South America (de Vries et al.1989) is a polyploid species with n=20, as is *R. aristatum* from Japan (Fritsch 1991) with n=21.

72. Racopilum cuspidigerum (Schwägr.) Aongstr. var. ***convolutaceum*** (Müll.Hal) Zanten & Dijkstra n=10 Figs 7.18 & 7.19

All Australian collections examined here belong to *R. cuspidigerum* var. *convolutaceum* (*12/75, 11/76, 33/79, 46/83*) and have the chromosome number n=10, supporting the previously published records for Australia.

Rhizogoniaceae

The family Rhizogoniaceae as recognised by Goffinet & Buck (2004) contains seven genera of which *Goniobryum, Hymenodon, Leptotheca, Mesochaete, Pyrrhobryum* and *Rhizogonium* are present in Australia. There are no chromosome data yet for *Goniobryum* or *Hymenodon*. Chromosome numbers already recorded for the family in Australia are n=10 and n=20 for *Leptotheca gauchaudii*; n=10 for *Mesochaete undulata;* n=5 for one species of *Rhizogonium* and n=6 and n=12 for two different species of *Pyrrhobryum* (Ramsay 1967a, 1974, 1982, 1983b, c). Some recent information is also available for *Pyrrhobryum spiniforme* n=12, for Papua New Guinea (Ramsay 2008) and for *Cryptopodium bartramioides* n=7 in New Zealand (Ramsay 2009).

73. Mesochaete undulata Lindb. n=10 Fig. 7.21

The chromosome number n=10 recorded by Ramsay (1967a, 1974) is supported in the recent studies for a collection (*36/83*) from Woolgoolga, New South Wales.

The subgenus *Pyrrhobryum* in the genus *Rhizogonium* was raised to generic level by Manuel (1981). In Australia *Pyrrhobryum* contains six species including the new species record *P. latifolium* while the genus *Rhizogonium* was reduced to four species by Gilmore (2006). Known chromosome numbers for species in Australia are n=6 and/or n=12 for several species of *Pyrrhobryum* (Ramsay 1966, 1967a, 1974, 1983c; as *Rhizogonium*), and n=5 for *Rhizogonium novaehollandiae* (Ramsay 1967a, 1974). The chromosome number n=12 has been reported for *Pyrrhobryum spiniforme* (Hedw)

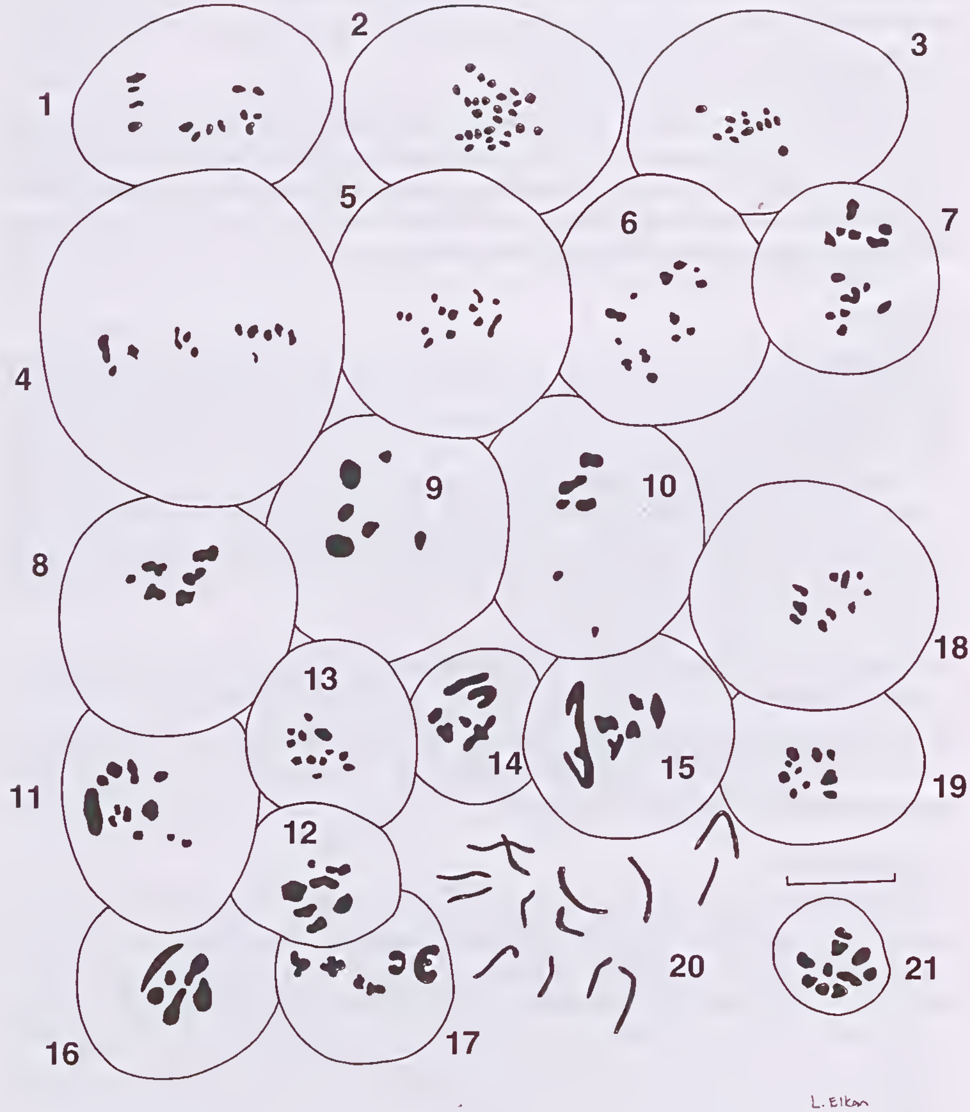

Fig. 7: 1–21. Chromosome numbers in Australian mosses (figures at metaphase 1 of meiosis unless stated otherwise) — in families Grimmiaceae, Pottiaceae (contd), Ptychomniaceae (part), Rhizogoniaceae, Racopilaceae, Mniaceae. **1.** *Grimmia trichophylla* (*17/84*) n=13; **2.** *Grimmia pulvinata* var. *africana* (*21/73*) n=26; **3.** *Schistidium apocarpum* (*49/82*) n=13; **4.** *Weissia brachycarpa* (*42/83*) n=12; **5–7.** *Weissia controversa*; **5.** (*13/84*) n=13; **6.**(*5/74*) n=13; **7.** (*9/76*) n=13; **8–11.** *Hampeella pallens*: **8.** (*33/81*) n=6; **9.** (*60/84*) n=6; **10.** (*50/83*) n=6; **11.** (*49/83*) n=12; **12.** *Ptychomnion aciculare* (*59/81*) n=7; **13.** *Pyrrhobryum mnioides* (*18/77*) n=12; **14 & 15.** *Pyrrhobryum paramattense*; **14.** (*2/82*) n=6; **15.** (*16/81*) n=6, note the large bivalent separating with unequal sized half bivalents; **16.** *Rhizogonium novaehollandiae* (*71/64*) n=5; **17.** *Pyrrhobryum medium* (*8/82*) n=6; **18 & 19.** *Racopilum strumiferum var. convolutaceum*: **18.** (*3/86*) n=10; **19.** (*33/79*) n=10; **20.** *Plagiomnium novae-zeelandiae* (*4/88*) n=14, gametophytic mitotic metaphase. **21.** *Mesochaete undulata* (*36/83*) n=10. Scale bar is 10 µm.

Mitt. from Japan, USA, Papua New Guinea (Fritsch 1991, Ramsay 2008) while n=6 is recorded from Japan and Puerto Rico. Although *P. spiniforme* occurs in Australia, no number is yet available for Australian collections.

Photomicrographs and a more detailed analysis of heteropycnosis, meiosis and mitotic chromosomes as karyotypes for *Pyrrhobryum* (as *Rhizogonium*) appear and are discussed in Ramsay (1974, 1982, 1983c) with locality data given for early collections in Ramsay (1967a) and for later collections here in Table 1.

74. Pyrrhobryum medium (Besch) Manuel n=6 Fig. 7.17

This species has a tropical distribution in Borneo, Papua New Guinea and the Pacific east to French Polynesia and in Australia occurs in northeastern Queensland (Gilmore 2006). The chromosome number for *Pyrrhobryum medium* (*1/64*) (as *Rhizogonium brevifolium*) was first recorded by Ramsay (1966, 1967a, 1974) with photomicrographs of meiotic figures (Ramsay 1966) and as figs 30–31 in Ramsay (1983c). Premeiotic chromosome studies appear in Ramsay (1966) and as karyotype figures in Ramsay (1982).

75. Pyrrhobryum mnioides (Hook.) Manuel n=12 Fig. 7.13

Streimann & Klazenga (2002) list this species in Australia as *P. mnioides* subsp. *contortum* (Wilson) Fife based on a revision by Fife (1995: 315) but this is not followed in Gilmore (2006: 362 who indicates no subspecies and does not quote Fife). The distribution of this species is southern temperate eastern Australia from New South Wales south to Tasmania and also on Macquarie Island extending across to New Zealand and South America.

Two separate collections of *Pyrrhobryum mnioides* were studied here (*16/77*, *18/77*) both from Victoria with the chromosome number n=12. A photomicrograph of metaphase 1 of meiosis appears in Ramsay (1983c: fig 106).

76. Pyrrhobryum paramattense (Müll.Hal.) Manuel n=6 Figs 7.14 & 7.15

Pyrrhobryum paramattense is distributed south from eastern coastal Queensland to New South Wales and Victoria and Tasmania. It also occurs on Norfolk Island (Streimann 2002) and in New Zealand (Beever et al. 1992). The chromosome number for *Pyrrhobryum* (as *Rhizogonium) paramattense* was recorded from meiotic and mitotic studies in Ramsay (1966) for five collections from Royal National Park, New South Wales (Ramsay 1967a, 1974). Here it is confirmed for an additional five collections (*2/72*, *11/75*, *16/81*, *17/81*, *8/82*) based on meiotic studies from different localities in northern New South Wales and Victoria and from mitotic examination of the karyotype (*12/79*) from Victoria. Photomicrographs appear in Ramsay (1966, 1983c: figs 22–25) showing the heteropycnotic structures at prophase 1 and illustrate the appearance of bivalents and their behaviour at metaphase 1 and anaphase 1. The additional collections examined here all had the chromosome number n=6.

77. Rhizogonium novaehollandiae (Brid.) Brid. n=5 Fig. 7.16

One of the four *Rhizogonium* species found in Australia (Gilmore 2006), *R. novaehollandiae,* has been examined cytologically with the chromosome number n=5 (Ramsay 1967a, 1974, 1983c) for a population from Tasmania (*71/64*) (Table 1). The chromosome number for *R. novaehollandiae* is illustrated by photomicrographs in Ramsay (1966, 1983c: figs 30 & 31). Drawings at metaphase 1 are included here.

Family Sematophyllaceae

The first chromosome counts published for Sematophyllaceae in Australia are n=11, 11(10+m) and 22 for *Rhaphidorrhynchium amoenum* (Ramsay 1967a, 1974), while other counts for *Wijkia extenuata* n=11, *Sematophyllum subhumile* n=11, and *Sematophyllum subpinnatum* n=10, appear in Ramsay et al. (2002). The genus *Wijkia* has been transferred to the new family Pylasiadelphaceae (Goffinet & Buck 2004), accepted by the above authors for the *Flora of Australia* 52A, Mosses 2 (in press). Other chromosome numbers (non Australian) have been reported for *Sematophyllum* n=10+m in USA; *Brotherella* n=6, 7, 8, 10, 9+2m in India, China, U.S.A and *Trichosteleum* n=11 in Vanuatu (see Fritsch 1991; Goldblatt & Johnson 1998).

The genus *Radulina* is a tropical moss widespread from India through Malesia to northern tropical Australia and Hawaii. The species recorded for Australia by Ramsay & Cairns (2004) and Ramsay et al. (2004) as *Radulina hamata* Dozy & Molk, has been synonymised with *Radulina borbonica* by O'Shea (2006).

78. Radulina borbonica (Bél.) W.R.Buck n=6 Fig. 4.11

This is the first chromosome count for the genus *Radulina*. The number n=6 is reported for a collection (*9/84*) made by Heinar Streimann in North Queensland, this being the lowest number for Sematophyllaceae in Australia, but n=6 is present in *Brotherella,* a northern hemisphere genus.

Family Thuidiaceae

The Thuidiaceae contains eight genera of well known pleurocarpous mosses of which *Pelekeium*, *Thuidiopsis* and *Thuidium* are known for Australia (Touw & Falter-van den Haak 1989). Chromosome data include n=11 for *Pelekenium* from India, n=10, 11 for *Thuidium* species from India, Japan, Europe, USA (Fritsch 1991, de Vries et al. 1989) and n=11, 22 for *Thuidiopsis sparsa* (as *Thuidium furfurosum*) from Australia (Ramsay 1967a, 1974).

79. Thuidiopsis sparsa (Hook.f. & Wilson) Broth. n=11 no illustration

The chromosome number recorded here for additional populations of *Thuidiopsis sparsa*, all from different areas in New South Wales: Katoomba (*2/75*), Macquarie University grounds in Sydney (*2/91*) and Mt Warning (*32/84*) is n=11 and confirms that found previously.

Family Trachylomataceae

The genus *Braithwaitea* was transferred from the family Hypnodendraceae to the Trachylomataceae by Buck & Goffinet (2004). The chromosome number n=10 was reported previously for *B. sulcata* in Australia by Ramsay (1983c, 1987).

80. Braithwaitea sulcata.(Hook.) Lindb. in A.Jaeger. n=10 Fig. 7.21

This report for *Braithwaitea sulcata* from an additional locality (*47/82*) confirms the chromosome number as n=10.

Discussion

There is a general consensus that studies of cytology of mosses, particularly concentrating on chromosome numbers and karyotype analysis, are significant in reflecting phylogeny, although there remain differences of opinion on interpretation (Newton 1984b). In a relatively recent study Przywara & Kuta (1995) have summarised cytological studies on bryophytes worldwide up until the mid 1990s. Their analyses encompass variation in chromosome numbers, distribution of cytotypes, basic chromosome numbers, the extent of polyploidy, aneuploidy, the distribution and frequency of m-chromosomes, intraspecific variability and geography with many comparative tables provided. In mosses, chromosome numbers vary from n=4 to 72 and it has been estimated that chromosome data are available for about 15% of mosses worldwide. At that time (1994) data were still unavailable for about 20 moss families, 442 genera and innumerable species.

Of particular interest among the new reports in these investigations are the chromosome number of n=6 for *Ceratodon purpureus* with a possible dimorphic bivalent, n=6 for *Leucobryum aduncum* var. *scalare*, and n=4 for an additional species of *Hypnodendron*, an Australian tropical endemic, *H. comatulum*. The first published chromosome number records are given for the genera *Calymperes* n=10, *Eccremidium* n=13, *Hampeella* n=6 & n=12, *Hedwigidium* n=11, *Tetrapterum* n=26 and *Radulina* n=6. First records are given here for Australian species in the genera *Aloina, Bryoerythrophyllum, Cryphaea, Dendrocryphaea, Encalypta, Grimmia, Gymnostomum, Hedwigia, Plagiomnium, Schistidium* and *Trematodon*. For species not previously studied the following chromosome numbers are reported: *Breutelia pseudophilonotis* n=6, *Entosthodon subnudus* var. *gracilis* n=26 & n=52, *Euptychium cuspidatum* n=5, *Garovaglia elegans* subsp. *dietrichiae* n=10, *Grimmia pulvinata* var. *africana* n=26, *Hypnodrendron comatulum n=4*, *Leptostomum erectum* n=6 & n=12, *Philonotis tenuis* n=6, *Rhynchostegium muricatulum* n=11 & n=22, *Tortella knightii* n=13 & n=20, *Tortula andersonii* n=22, *Tortula antarctica* n=26, *Tortula atrovirens* n=21, *Weissia brachycarpa* n=13 (Table 1).

More recently, molecular studies such as electrophoretic enzyme methods allow genetic polymorphisms to be revealed in populations or confirm hybridisation or polyploid origins. Such analyses based on nuclear DNA and comparisons of mitochondrial and chloroplast genomes are adding more information for cytogenetic and phylogenetic research in mosses (Vitt et al.1998, Goffinet et al. 2004). It is possible that molecular together with cytological studies will prove valuable information for a variety of investigations such as those in progress on *Sphagnum* (Shaw pers. comm.).

Chromosome studies both at meiosis (chromosome numbers, heterochromatin during prophase, its distribution on the individual chromosomes, meiotic behaviour such as pairing and chiasma formation and various specialised chromosomes and erratic behaviour) and at mitosis (karyotype comparisons, heterochromatin banding, distinguishing between autopolyploidy and allopolyploidy and the origin of aneuploidy within complements) continue to provide important information on origins and significance of evolutionary processes in mosses (Newton 1984b). Cytogenetic studies can provide analyses of possible sex determining chromosomes, either structural or morphological (Ramsay 1983c), provide data for the cytogeographical occurrences and indicate the importance of polyploidy and aneuploidy in both the evolution and

distribution of mosses (Newton 1979, 1984b; Przywara & Kuta 1995). Cytological differences, either numerical or structural between taxa or even within populations, can indicate and eventually provide information on the phylogeny of mosses. Differential staining methods such as Geimsa c-banding analyses which differentiate the distribution of euchromatin and heterochromatin (facultative and constitutive) within the karyotype for the cytogenetics of mosses has been clearly demonstrated by Newton (1977, 1983a, 1984a, b, 1985, 1986).These methods have great taxonomic potential but have been carried out rarely on mosses. No such data are yet available for any Australian moss.

There is still much to be investigated. In spite of the large volume of data available for the mosses in the northern hemisphere, where most of the research work has been undertaken so far, more than 80% species there have yet to be checked. Even with the additional chromosome data presented here, the available information for mosses in Australia still covers no more than 15 % of total species here, so there is a need for continuing cytological studies in this continent. The almost complete absence of chromosome studies of mosses in other regions of the southern hemisphere such as the continents of Africa and Central and South America as well as Pacific Island Territories, where some interesting and unusual mosses occur, certainly calls for further investigation.

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